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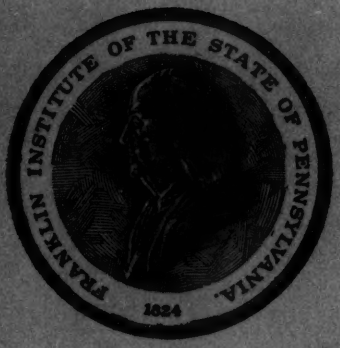
1826  **1946**

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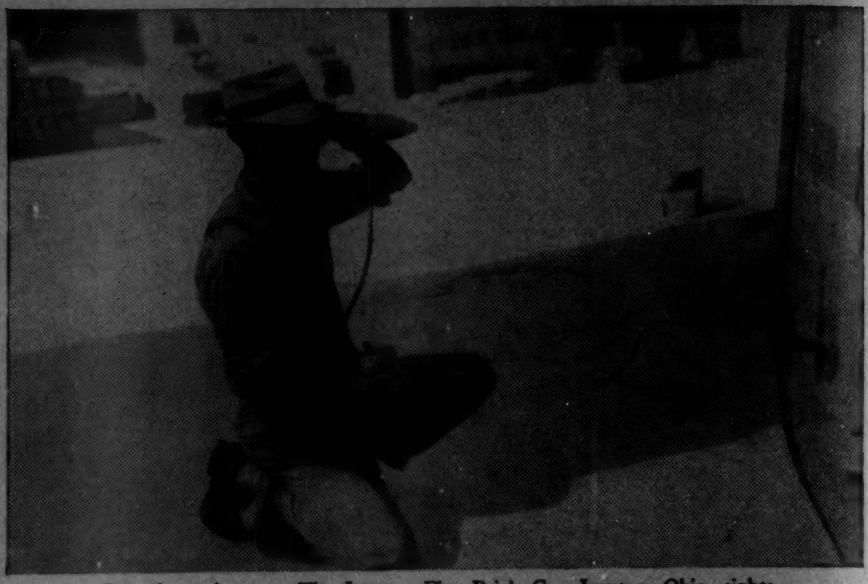

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Vol. 241 MAY, 1946 No. 5

STUDIES IN THE SENSITIVITY OF PHOTOGRAPHIC MATERIALS. IV. A TENTATIVE EXPLANATION OF THE INTRINSIC SENSITIVITY.

BY

A. P. H. TRIVELLI.

Communication No. 1076 from the Kodak Research Laboratories.

In Part III [1] of this series of papers, experimental evidence was given to support the view that the intrinsic sensitivity of a photographic emulsion for daylight exposures is not measured by the absorption coefficient of the silver halide of the grains, κ, but by a much smaller numerical value, ϵ, which can be called the effective absorption coefficient of the grain in latent-image formation. Only for x-ray exposures was it found that the intrinsic sensitivity is measured by the absorption coefficient. If this were true for blue-light exposures with a value of $\kappa = 0.10$ for $\lambda = 436$ mμ, chemical sensitizing of an unsensitized emulsion would be detectable by an increase in its opacity. This does not agree with the observations.

In the initial stages of the development of his exposure theory, Silberstein [2] assumed that each grain of a photographic emulsion required approximately the same number, r, of effective quanta to make it developable. This value of r was regarded as an average of a range of different values distributed among the grains according to a very steep probability curve.[2] In a later theoretical investigation, Silberstein [3] found that r has a unique value for all grains of an emulsion with a simple characteristic curve. If, on the other hand, there are some grains in an emulsion which require two effective quanta and other grains which require three effective quanta to make them developable,

[1] A. P. H. Trivelli, *J. Franklin Inst.*, **241**: 85, 1946.

[2] L. Silberstein, *J. Opt. Soc. Am.*, **31**: 343, 1941.

[3] L. Silberstein, Private Communication.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

such an emulsion would not produce a simple but a complex characteristic curve, which can be split into two- and three-quantic components.

R. P. Loveland and the author found experimental evidence of this conclusion in their investigations of the sensitivities of grains of different sizes of the same emulsion. The measurements were made on one-grain-layer coatings, which were exposed under sensitometric control and developed until nearly maximum "contrast." Several experiments were made with different emulsions and different developers. As an example, results obtained from a Seed Lantern emulsion having an average grain size, $\bar{a} = 0.26\ \mu^2$, and a dispersion of grain sizes,

TABLE I.

Curve	Range of grain sizes in μ^2 in each class	Average grain size in μ^2 of each class	Number of grains measured
1	0.03–0.2	0.12	47,160
2	0.2 –0.4	0.3	19,090
3	0.4 –0.6	0.5	2,045
4	0.6 –0.8	0.7	208

TABLE II.

$\frac{k}{N}$ log E—*Values for Different Class Sizes.*

Log E	Average grain sizes of the classes in μ^2			
	0.12	0.3	0.5	0.7
0.60	—	13.1	25.3	52.0
0.75	—	19.0	45.9	73.8
0.90	2.6	30.9	69.1	85.0
1.05	10.6	51.3	85.1	94.7
1.20	30.4	76.3	93.4	98.0
1.35	52.0	88.1	96.7	98.8
1.51	72.4	93.3	98.9	100.
1.66	82.9	95.7	99.5	
1.81	89.3	98.0	99.9	
1.96	93.0	99.4	100.	
2.11	96.1	99.8		

$\sigma = 0.17\ \mu^2$, are taken. These data show relatively small differences in the grain sizes of this emulsion. This, however, increases the chance of obtaining more reliable data.

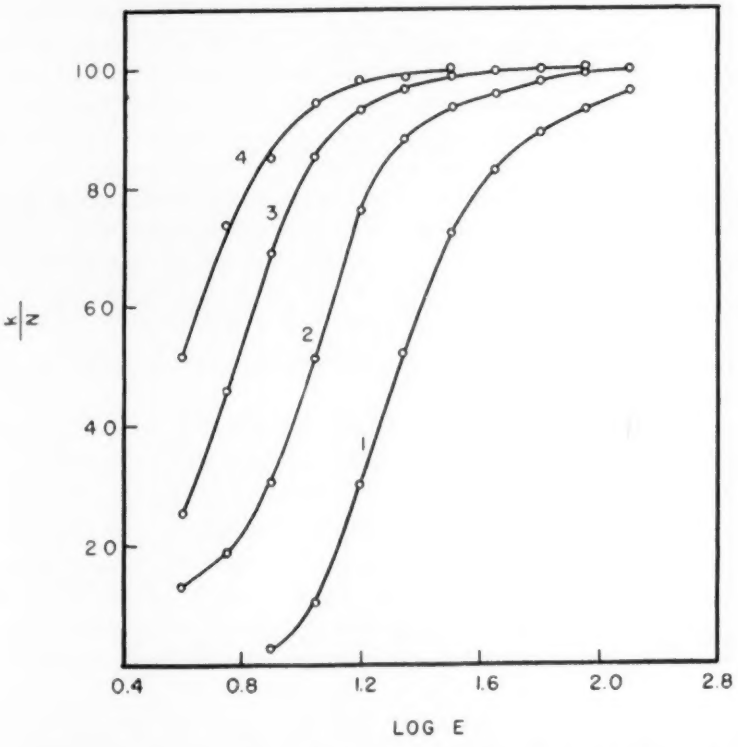
If, with exposures, E, k out of N grains become developable, then $\frac{k}{N}$ plotted against the logarithm of the exposures will give curves which are characteristic in shape for the quantum number, r, of an emulsion.[4] This holds also for curves obtained with grains of uniform sizes and with grains having a narrow range of sizes. If the grains of a

[4] L. Silberstein and A. P. H. Trivelli, *J. Opt. Soc. Am.*, **35**: 93, 1945.

certain size require a different number of effective quanta to make them more developable than grains of another size, the shapes of the $\frac{k}{N}$ log E curves are different for different grain sizes. If they have the same shape, this is an indication that grains of different sizes require the same number of effective quanta to make them developable.

Information was obtained with four classes of grains, each having a narrow range of grain sizes, which are given in Table I, together with

FIG. 1



the average grain size of each class and the number of grains measured in each class.

The values of $\frac{k}{N}$ at the different exposures for the different classes are given in Table II.

These data are plotted in Fig. 1. It is noticeable that Curve 4 is incomplete. However, the shoulder of this curve is useful for the investigation. For classes with still larger average grain sizes, the curves become more incomplete and, therefore, less useful. For this reason the investigation has been restricted to these four class sizes.

The maximum slopes of these curves, 1 through 4, measured on the graph, are 3.0, 3.5, 3.2, and 3.4, respectively, with N as a constant. The close values of these slopes for the curves, 2, 3, and 4, indicate that they are congruent. By superimposing these curves it can easily be shown that they have the same shape and size within experimental errors. This means that all the grains with an average grain size between 0.3 and 0.7 μ^2, inclusive, require the same number of effective quanta to make them developable, which agrees with Silberstein's conclusion of the uniqueness of r for all the grains of a simple emulsion.

It can be observed that the shape of Curve 1 produced by grains with a range of sizes from 0.03 to 0.2 μ^2 deviates decidedly from the shape of the other curves. This is in agreement with similar observations in other emulsions. The smallest grains lie so near the limit of the resolving power of the microscope that an error in the grain count is unavoidable. In addition, these grains are extremely reactive with chemical densenitizers. It has been found in one emulsion with an average grain size of $\bar{a} = 0.50\ \mu^2$ that these grains do not even enter in the prolonged development of the maximum density of its characteristic curve. These two factors are sufficiently effective to change the shape of the $\frac{k}{N} \log E$ curve of the first class of grain sizes. The value of r is, therefore, a constant for grains of different sizes in an emulsion having a simple characteristic curve.

This is not the case with the intrinsic sensitivity, ϵ, of all the grains in an emulsion. The shifts of the inflection points of the curves, 2, 3, and 4, in Fig. 1 show definitely that the intrinsic sensitivity of the grains increases with their size. F. L. Righter, Sheppard, and the author[5] found that statistically the probability of a clump of grains becoming developable by exposure is equal to the sum of the probabilities of its component grains becoming developable by a certain exposure. In other words, the grain clumps in photographic emulsions behave as single large grains.

If grains of different sizes are exposed, the number of incident quanta per grain is directly proportional to the projective area of the grain. Since the effective number of quanta, r, is a constant for all grain sizes, it is evident by definition that the intrinsic sensitivity of a grain is proportional to its projective area. This holds only for grains in the same simple emulsion. In measuring the intrinsic sensitivity of an emulsion we are, therefore, dealing with the intrinsic sensitivity of the average grain size, $\bar{a}$, of the emulsion. It was found theoretically that this value is a constant for all exposures necessary to produce simple characteristic curves from zero to maximum density. The value

[5] F. L. Righter, S. E. Sheppard, and A. P. H. Trivelli, *Phot. J.*, **62**: 407, 1922.

of ϵ must, therefore, be a constant at all densities of simple characteristic curves.

The intrinsic sensitivity of a two-quantic emulsion, for instance, is measured by the reciprocal value of the number of incident quanta which are required to produce by development the density at the inflection point of the characteristic curve. The densities around this point offer the best chance to obtain the average values of ϵ among variations at the other densities due to experimental errors.

An example of the distribution of the magnitude of these variations of ϵ over the different observed densities of a two-quantic characteristic curve will be given. The equation of such a curve [6] is:

$$\frac{D}{D_{\max.}} = \frac{y^2(3 + y)}{(1 + y)^3}, \tag{1}$$

in which

$$y = \epsilon \bar{a} n. \tag{2}$$

In these equations D and $D_{\max.}$ are the density and the maximum density of an emulsion having an exponential grain size distribution and an average grain size, $\bar{a}$, in μ^2, and n is the number of incident quanta per square centimeter of emulsion layer, which, after development, produces the densities of its characteristic curve.

From (1) and (2), the following equations, (3) and (4), can be derived:

$$\log \epsilon = \bar{1}6.293 - \log (\lambda \bar{a}) + \log y - \log E, \tag{3}$$

in which

$$y = \frac{2}{\sqrt{1 - \vartheta}} \cos \{60^\circ - \tfrac{1}{3} \arccos \sqrt{1 - \vartheta}\} - 1, \tag{4}$$

and

$$\vartheta = \frac{D}{D_{\max.}}.$$

In Equation (3) λ is the wavelength of the incident radiation in centimeters and $\log E$ is the logarithm of the exposure in ergs per square centimeter of emulsion layer.

A characteristic curve with a maximum density of $D_{\max.} = 1.24$ was obtained by a series of sensitometrically controlled exposures, E, at a wavelength of $\lambda = 426$ mμ on an emulsion layer having an average grain size of $\bar{a} = 0.82\ \mu^2$. Development was accomplished in 5 minutes in a DK-50 developer at a temperature of 20° C. From the observed densities, $D_{\text{obs.}}$, obtained with the exposures, $\log E$, the following values of $\epsilon \times 10^4$ were determined:

Log E:	$\bar{1}.87$	0.17	0.47	0.77	1.07	1.37
$D_{\text{obs.}}$:	0.12	0.34	0.62	0.88	1.08	1.21
$\epsilon \times 10^4$:	1.81	2.00	1.91	1.73	1.65	2.34

[6] L. Silberstein and A. P. H. Trivelli, *J. Opt. Soc. Am.*, **35**: 93, 1945.

giving an average value of $\bar{\epsilon} = 1.91 \times 10^{-4}$, which compares very closely with the value of $\epsilon = 1.89 \times 10^{-4}$ for the density at the inflection point of the characteristic curve.

We arrive at the following conclusions:

(1) The number of effective quanta to make a grain developable is the same for all grain sizes and for all exposure times.

(2) The intrinsic sensitivity of the average grain size is the same at all exposures, but is not the same for all grain sizes. It is proportional to the grain size.

Both conclusions have to be taken into consideration in any explanation of the magnitude of the value of ϵ as a fraction of the absorption coefficient of the silver halide of the grains.

Equation (2), which gives the exposure exponent, y, of the uniform grain sizes in a photographic emulsion, can be written:

$$y = (\epsilon n)\bar{a} \quad \text{or} \quad y = (\epsilon \bar{a})n.$$

The first form expresses the concept that grains with a size $\bar{a}$ require at least ϵn effective quanta to become developable at the minimum exposure to introduce developability, n. With larger grain sizes, ϵ becomes proportionally greater and n can, therefore, be taken proportionally smaller to produce the same effect. Increasing the number of incident quanta after the grain has absorbed its required number of effective quanta does not make any change in the grain, except at extremely long exposures, with which we are not dealing here. It has, however, a great effect upon an assemblage of a number of grains. The number of developable grains increases as expressed by Equation (2).

The second form leads to the unavoidable conclusion that with a minimum exposure of n incident quanta upon the projective area, $\bar{a}$, of the grain, only a small fraction of this area, $\epsilon\bar{a}$, is effective in latent-image formation. The sensitivity of a grain can, therefore, be defined as the chance of r effective quanta out of n incident quanta being absorbed by $\epsilon\bar{a}$, a fraction of the projective area of the grain.

It is a well-known fact that chemical treatment of a photographic emulsion affects its sensitivity. Such effects are measurable by the changes in the values of ϵ and r, as shown in Part III of this series of papers. We shall deal here with a tentative interpretation of ϵ. Therefore, no special attention will be given to the changes of ϵ and r produced by sensitizing or desensitizing the emulsion. For exposures in the short-wave region of the visible spectrum, the sensitivity of a grain does not depend upon the structure of the incident radiation alone but also upon the structure and the constitution of the grain. The quantum theory of exposure does not attempt to portray the structure of the surface of the grain. Other hypothetical pictures have been proposed to explain events in latent-image formation and have been shown to be useful

working hypotheses but not final explanations. The quantum theory of exposure has been developed independently of these hypotheses. However, it is so closely connected with these hypotheses that the results can be applied to a probable picture of latent-image formation. On the other hand, such an application offers at the same time a tentative explanation of the fact that ϵ, which measures the sensitivity, is only a small fraction of the absorption coefficient of the silver halide of the grains.

Up to the present time the most promising latent-image hypothesis has been offered by Gurney and Mott.[7] These investigators suggested a mechanism for the production of an image in exposed silver halide grains. This picture, based upon well-established principles of physics, has furnished a qualitative explanation of a number of features.

According to this hypothesis, the total number of quanta absorbed make the silver halide of a grain photoconductive, liberating a number of very fast moving electrons and the same number of slower-moving positively charged silver ions. The photolytic effect can be represented by the well-known equation:

$$Ag^+Br^- + h\nu \rightarrow Ag^+ + Br + \ominus.$$

The bromide anion losing its electron becomes electrolytically immobile and highly reactive chemically as atomic bromine.

The surface of the silver halide grain contains a large number of sensitivity specks. The author assumes that these specks of silver sulfide form energy traps for the moving electrons. This gives the sensitivity specks a negative charge. The specks attract the positively charged silver ions, which move towards them and are neutralized at the interface between the speck and the surrounding silver halide.

The moving electrons are distributed over the surface of the silver halide between the different energy traps according to the laws of probability. This is the so-called competition effect of the specks in the concentration speck hypothesis of Sheppard, Trivelli, and Loveland,[8] which has been applied in the Gurney and Mott hypothesis and leads to the conclusion that the number of effective quanta can be no more than a fraction of the number of quanta absorbed, depending upon the number and the distribution of sensitivity specks on the grain. The sensitivity speck which, during exposure, collected the first r silver atoms necessary to introduce developability must be considered as the development center which determines the sensitivity of the grain.

The sensitivity speck is surrounded by an environment of silver halide, in which electrons and silver cations move during exposure. The number of effective r silver cations is collected by the speck from

[7] R. W. Gurney and N. F. Mott, *Proc. Roy. Soc.*, **164A**: 151, 1938.

[8] S. E. Sheppard, A. P. H. Trivelli, and R. P. Loveland, *J. Franklin Inst.*, **200**: 51, 1925.

this environment. This environment is the effective surface, $\epsilon\bar{a}$, for latent-image formation. It is, therefore, not equal to the total projective area of the grain.

The low values of r generally obtained indicate that as a rule only a few silver atoms, located at the interface between the sensitivity speck and the silver halide, are sufficient to introduce developability. This is the location of the latent image on the surface of the grain. Development, therefore, has to start somewhere at the interface between the silver halide and the speck of the grain.

ROCHESTER 4, N. Y.,
February 25, 1946.

EMERGENT ENERGY.

BY

GUSTAF STRÖMBERG.

Pasadena, California.

> Modern Physics impresses us particularly with the truth of the old doctrine which teaches that there are realities existing apart from our sense-perceptions, and that there are problems and conflicts where these realities are of greater value for us than the richest treasures of the world of experience.
>
> *Max Planck* in *The Universe in the Light of Modern Physics.*

The concept of energy is not very old in the history of physics. The reason for its late introduction in this science was largely the fact that energy does not intrude into the world of our experience in the same direct way as do, for instance, weight, mass, and force. It is an indirectly measured quantity that remains unchanged during even the most far-reaching transformations. Apparently it must represent some significant essence in the external world, and anything that can throw light on its more fundamental nature would be of importance for our understanding of the world around us.

Modern discoveries concerning the elementary processes in physics have revealed the fact that both matter and radiation have "corpuscular" properties as well as "wave" properties. The so-called corpuscular properties become particularly evident when these processes are observed as highly localized events of very short duration involving definite amounts of energy, mass, and electric charge. The so-called wave properties are manifest in different ways. The most direct way of observing them is by studies of the statistical distribution of the location and the time of the individual events. This is followed by the development of a geometrical interpretation or, preferably, by a mathematical analysis which furnishes the general rules for the computation of the statistical distribution pattern. When these rules have been established, it is possible to make predictions of a statistical nature. These rules can therefore be regarded as furnishing a method of deriving a *potential* statistical distribution of discrete events, whereas the directly observed events represent an *actual, specific* distribution. Since all the events here considered are associated with definite amounts of energy, the wave nature of matter and radiation can be regarded as describing energy in a ***potential*** form, whereas the directly observed corpuscular nature of matter and radiation represents energy in an *actual* or *effective* form. When individual physical events are considered, potential energy can therefore be regarded as defining the *probability* of definite

amounts of energy, mass, and electric charge momentarily *emerging* in an observable form at a particular place and time.

This is in its simplest terms the essence of the theory of *emergent energy*. This theory is intimately connected with that of the *autonomous field*, the development of which has been described in previous publications by the writer.[1,2,3] The autonomous-field theory has lately received strong support by the discovery of oscillating electric fields associated with all living organisms and apparently primarily responsible for their marvelous organization and functions. On the basis of these theories we shall now analyze certain fundamental problems in physics and also make an attempt to trace energy to its ultimate origin.

EMERGENCE OF PHOTONS.

Let us first take a simple example from physical optics. We imagine a point source of light which sends a beam of light through two apertures and through an image-forming lens. An interference pattern is then observed in the focal plane of the lens. We shall assume that the light is monochromatic and so weak that at any moment only one photon is emitted. We can imagine the source of light to be a small aperture transmitting light from a discharge tube, the opening being covered by a dense color filter which transmits one spectral line only and greatly reduces the intensity of the light. The interference pattern is supposed to be photographed on a sensitive plate using a long exposure. That an interference image can be obtained under such conditions was first shown by Taylor.[4] Huygens's highly significant construction of wave fronts as the envelope of secondary wavelets applies also to the two apertures from which two coherent wave systems emerge and jointly produce the interference pattern.

It is stated that interference can only take place if the interfering beams come from the same source. But what do we really imply by this statement? If several atoms in the same source of light are emitting light at the same time, the light impulses from the different atoms ordinarily have no fixed phase relations, and the waves from the different atoms, even if the wave lengths were exactly alike, would not reinforce or annul one another at points fixed in the image plane. Two or more beams of light therefore can produce an observable interference pattern only if they contain time elements originating in the *same* atom and in the *same* emission process. In the photon theory of light this is expressed by the statement that "a photon can only interfere with itself." The interference pattern must therefore be regarded as a sum of independent effects each of which is produced by an *individual atomic event*. Having the same origin the interfering waves have also the same initial state of polarization, another condition for interference.

The corpuscular theory of light is just as well established as the wave theory of light. The most direct evidence for the corpuscular theory

is offered by the photo-electric effect and the Compton effect. These show that light acts as corpuscles (photons) carrying an energy $h\nu$, a linear momentum $h\nu/c$, and an effective mass, entirely due to their motion, equal to $h\nu/c^2$. Here h is Planck's constant (the quantum of action), ν is the frequency of the light, and c is the velocity of light *in vacuo*. If we could observe the effect of individual photons, we would see scintillations occurring with high frequency at those places where the intensity of the interference pattern is a maximum, and not at all where this intensity is zero. Again we find that the observed interference pattern must be regarded as an integration of a great number of independent, elementary effects.

Many attempts have been made to reconcile the wave nature and the corpuscular nature of light, but all attempts made so far are of a formal nature. The most generally accepted theory is that of "superposition of states," a very important theory of great generality that has been developed in great detail by Dirac.[5] The theory states that, although a photon carries momentum and is in a definite state of polarization, it is not confined to any particular path. In fact, in the general case each individual photon must be pictured as "distributed" over the whole wave front. In our case of two apertures the photon with its momentum and state of polarization must therefore be regarded as existing in *both* beams. If we think that this may be due to our ignorance and make an attempt to find out in which of the beams the photon moves, the attempt itself alters the conditions in such a way that the photon appears to be completely in one beam or the other. In Dirac's picturesque language "it is forced entirely into one of the beams by an observation." If no such attempt is made, the result of our observations, e.g., the distribution of photons in the interference pattern, can be predicted as the result of a superposition of states. Einstein, Podolsky, and Rosen [6] have called attention to an apparent incompleteness in the quantum mechanical description, which leads to an apparently insoluble dilemma. The question has been further discussed by Bohr [7] and by Epstein.[8]

The theory of superposition of states is mathematically consistent and very useful, but can hardly be regarded as entirely satisfactory from a logical standpoint. The writer believes that the logical difficulties are due to the fact that while photons are known to *act* as corpuscles, this does not prove that they *move* like corpuscles are supposed to move. Nobody has ever observed a photon *in transit*. Such an observation is in principle impossible, since any attempt to observe it in transit either gives no result at all, or else we observe a photon *in action*. In the imaginary and often cited case of an attempt to fix the position of a photon by letting it be reflected by an exceedingly light mirror and observing the recoil, the present theory asserts that linear momentum can occur in a dispersed as well as in a concentrated form, and

the *dispersed* form can be arbitrarily divided and vectorially combined. The dispersed form defines the probability of mechanical effects on reflectors. Such effects are associated with the emergent form of mass, which has properties analogous to those of emergent energy. We never observe a part of a photon, and it seems to the writer that we should, if possible, avoid using such parts in our imagery. The wave structure of the radiation determines the *probability* that a photon will be observed at a particular place and time. If we insist upon thinking about something in motion, this something is a structure defining this probability. Such a structure can be described as a "potentially dispersed photon" or as a "field element" in the radiation field, and it is described by the wave characteristics of the radiation.

The here assumed non-existence of corpuscular photons in transit disposes of another problem. Moving photons are supposed to be associated with radiation of high frequency, but not with radiation of low frequency. The latter is supposed directly to influence the motions of electrons, as in the antenna of a radio receiver. In the present theory there are no moving photons and, as we shall explain later, not even any moving electrons. What happens at the receiving end is due to the combined effect of the two fields: the moving radiation field, and the field in the receiver. Under certain conditions a photon may emerge as the observable result of the interaction; in other cases an individual electron may make a momentary effect on a sensitive instrument. The conservation laws of physics are valid, provided we admit energy, mass, momentum, and electric charge as potentialities. An interesting example is offered by the light from a distant extra-galactic nebula. An element of energy involved, produced by an individual atomic event at an enormous distance from the earth, may be unobserved and inactive for thousands of years until it reaches a photographic plate on the earth. Whether or not the energy "exists" when in transit is entirely a question of definition of terms. The writer prefers to think of it as non-existing *as energy*, but existing as a *potentiality*. Its energy is like that of a stone on the top of a mountain. Some time in the unpredictable future the stone may roll down, and its potentialities may be revealed, that is, they emerge as actualities in the world of our experience.

Energy, mass, and momentum are all measured quantities which depend on the motion of the observer relative to the observed object. They seem to disappear at one place and reappear later at another place with a retention of their characteristics. Looking at the phenomena of radiation from this viewpoint, we realize that it is perfectly logical to state that, when an observation is made, mass, energy, and momentum *emerge* for a moment into the observer's framework of space and time, and that the emergence is governed by a probability structure. In transit, mass, energy, and momentum are unobservable,

but may conveniently be regarded as potentialities for the description of which we can use any appropriate mathematical functions. Hence, by entirely eliminating the moving, corpuscular photons from our pictures and replacing them by a set of potentialities, expressed on the physical level of description as probabilities, we can improve the logical structure of the current theory without in any way modifying its mathematical formulation.

EMERGENCE OF ELECTRONS.

Applied to photons the theory of emergent energy is not new, since very similar ideas, although clothed in a different language, are inherent in most quantum mechanical theories. A novel feature, however, is encountered when it is applied to what we usually call "particles in motion." To realize the implication of the theory we shall describe the often cited example of a homogeneous electron beam passing through two slits very close together. We then observe, or rather expect to observe, a diffraction pattern similar to that produced by a beam of monochromatic light. The "wave length" of an electron, first derived by De Broglie, is equal to the quantum of action divided by the momentum of the electron. We are used to picture electrons as moving corpuscles, and we are therefore not surprised if we observe scintillations when they hit a fluorescent screen, although we may be surprised to find a pattern similar to that produced by light. As in the case of photons, the distribution of the scintillations must be the same whether they are one or many electrons moving through the slits at any moment. If we consider single electrons and picture them as small, moving corpuscles, we arrive at the conclusion that the transmission of an electron is just as much determined by the slit through which it does not pass as by the slit through which it actually passes.

Assuming that nature is rational we can expect that there is something wrong in our picture of electrons as moving, identifiable bodies. It is easy to see that the weak part in the reasoning is exactly the same as in the case of "moving photons." Individual electrons, like photons, can be observed *in action*, but never in transit. Since the very idea of individual electrons in motion leads to logical difficulties and contradictions, we must replace it by other concepts. These new concepts are those previously referred to, namely potential mass, energy, momentum, and electric charge. They are all included in the wave characteristics of the electrons, but in the present theory *they are not caused by or even associated with any moving corpuscles.*

The idea of a potential mass is of great interest and throws much light on the nature of this mysterious property which prevents us from moving matter in any way we please and at the same time is a measure of gravitational action. An electron, in contradistinction to a photon, has a finite rest mass, nevertheless, it does not travel in any particular

path like those we are accustomed to observe in the case of heavier bodies. Mass elements in general should therefore not be pictured as highly localized corpuscles moving from one place to another. Mass is a *form* as well as a *measure* of energy, and we can therefore expect it to have properties similar to other forms of energy. On the basis of this analogy we may picture mass as having a diffuse, potential form, as well as a highly concentrated, effective form. The former should be included in the wave characteristics of a mass element, and the latter should be described by its corpuscular properties. From our experience with photons we should then expect that, at the moment of an emergence, the diffuse form, however large its extension may be, momentarily goes over into the concentrated form. We also arrive at the very important conclusion that the diffuse, potential form of mass is identical with a gravitational field, and the diffuse, potential form of electric charge is identical with an electrical field. Ordinary large-scale manifestations of mass and electrical charge must then be attributed to the diffuse form and are of a more or less permanent type, whereas the small-scale manifestations, as observed in the Compton effect and the photo-electric effects, for instance, are manifestations of mass and charge in their concentrated, transient form.

In the quantum theory the combined position and motions of electrons are usually defined by a "wave packet," which in the general case must be represented in multi-dimensional configuration space. This is in complete harmony with the ideas previously expressed for radiation. The wave packets do not "guide" the motion of electrons in transit, as was once suggested by De Broglie. Instead, they represent units of potentiality defining the probability distribution for the emergence of a definite amount of charge, mass, and momentum into the physical world. In describing this potentiality we can, as in a diagram, use as many dimensions or variables as there are independent characteristics. The electric charge of an electron is a characteristic of a field unit that determines its relationship in space and time to other similar field units. At an emergence a definite and highly localized charge seems to emerge from a field unit, since electric charge is preserved and has a well defined meaning in transit, although the individual electrons have no such meaning. Electrons, like photons and other corpuscles, can be regarded as having a momentary existence only and should therefore not be regarded as moving or as acting on one another. In the autonomous-field theory, which is inseparably connected with that of emergent energy, all interactions are *field effects*, and the corpuscles are emergent and evanescent *indicators*, but not the cause of force fields.

It has long been known that the path of a moving body from an initial point to a fixed endpoint is governed by Hamilton's principle, which is the modern form of the principle of least action. The potential energy, which is a characteristic of the field, naturally plays an im-

portant role in determining this path. From the standpoint of the present theory, in which there are no moving corpuscles, this implies that the potential functions which determine the probability of the emergence of a corpuscle must have a structure that conforms to Hamilton's principle, a fact of the greatest importance in formulating the wave properties of matter. This applies also to the propagation of light. They should also have a structure that satisfies the invariance of the theory of relativity.

EMERGENCE OF ATOMIC NUCLEI.

It has been shown that protons, the nuclei of the hydrogen atoms, also are associated with waves. Because of the greater mass of a proton, its wavelength is much smaller than that of an electron moving at the same speed. There can be no doubt that all atomic nuclei, even the heaviest ones, are associated with waves. An atomic nucleus is supposed to be extremely small and could therefore be expected to go through the smallest openings in any kind of material structure. If we imagine a grating with an extremely small grating space transmitting a beam of atomic nuclei, we should expect to observe a diffraction pattern of the same type as for electrons, although of much finer structure. The argument previously given for electrons, showing that they are not moving as corpuscles although they manifest themselves as such, therefore holds in principle for atomic nuclei as well. If we think of an atomic nucleus as a small corpuscle, we must picture it, like a photon or an electron, as being in many places at the same time. In transit they should therefore be described as potentialities in configuration space, rather than as actualities in physical space.

The same holds for atomic nuclei at rest, or nearly so, relative to the observer. If we bombard a body with alpha particles, a few of them have apparently collided with atomic nuclei. In the last case a new type of atomic nuclei may be produced. The position of the nuclei is determined *a posteriori* from the deflections, and the regularities in the observations therefore give us a set of probabilities that can be used for predictions. Most people would say that it is plain common sense to believe that the atomic nuclei exist *as such* even when they are not observed. Modern science has learned by sad experience that we can not trust our "common sense" when we try to describe the external world as something apart from or even of the same type as that of the world of our experience. Our observations tell us that we can describe matter as a set of potentialities statistically defining where we can expect mass, momentum, and charge to appear. We may therefore well say that the concentrated mass, energy, and charge of the atomic nuclei emerge as actualities in the world of our experience when those observations are made which we interpret as evidence of their existence.

It should be noted that according to the present theory the diffrac-

tion of x-rays in a crystal is a field effect and not a particle effect, that is, it is produced by atomic nuclei in their diffuse, potential, and relatively permanent form, but not by nuclei in their concentrated, corpuscular, and transient form. If there is no absorption and re-emission of the radiation inside the crystal, no emergence of energy takes place in the transmission process. In order that observable effects may be produced, however, energy elements must for an instant emerge at the recording instrument, e.g., in the sensitive, unstable grains of a photographic emulsion.

The introduction of emergent mass, momenta, and energy makes it necessary to change our concept of matter in continuous motion, which is one of mankind's oldest ideas. It is not difficult to see that this idea is the result of the crudeness of our sense organs, a crudeness that has been revealed to us by the introduction of highly sensitive scientific instruments. If our sense of vision were more acute and had greater resolving power in space and in time, we would see a moving body as a group of scintillations of extremely short duration. The scintillations themselves would probably not move at all, instead new ones would appear progressively in new positions, just as in the moving pictures we see on a screen, when the pictures are changing very slowly. The scintillations would occur if the moving body were illuminated by a source of light, if it were incandescent, if it consisted of a radio-active substance and we studied the "ejected" corpuscles and photons, or if we observed corpuscles reflected or transmitted by the body. In the moving pictures the things that actually move are *patterns*, which themselves change relatively slowly. In matter it is the *field structure* that moves, and not the corpuscles involved. The error that has crept into our scientific thinking is that we have taken over the old idea of solid matter in continuous motion, forced on us by the crudeness of our organs of perception, and have applied it as a characteristic of the elements of matter. When this idea of moving corpuscles is abandoned, our difficulties in obtaining a unified picture of the corpuscular nature and the wave nature of matter and radiation disappear.

In the present theory a velocity is regarded as a *statistical* characteristic of a field pattern applicable to *systems* of atoms and therefore to the observer himself, his instruments, and to the water drops in his cloud chambers, etc., but not in any directly observable form to the individual field units or to the individual corpuscles. It is therefore necessary to express momentum and energy in terms which do not explicitly involve any motion. We can replace the conventional velocity of a corpuscle by an inherent space-time interval, ds, or, better still, by its corresponding proper-time interval, $d\tau = ds/ic$, these intervals being equal to zero for a photon. The total energy E of a corpuscle of effective mass m and rest mass m_0 is equal to $mc^2 = m_0c^2dt/d\tau$, where dt is the inherent time interval mentioned as determined by a particular

observer and therefore dependent upon his motion. Its momentum is equal to h/λ, where λ is an associated wavelength. This momentum is numerically equal to $\sqrt{E^2 - E_0^2}/c$, where $E_0 = m_0c^2$ is the energy corresponding to the rest mass of the corpuscle. The kinetic energy of the corpuscle is equal to $E - E_0$, which for a (statistically determined) moderate velocity v of a body of mass M has the value $Mv^2/2$, the expression familiar from classical mechanics.

In describing our knowledge of matter from the point of view of the theory of emergent energy I can do no better than repeat a statement made in an earlier publication.[9] "In our direct vision, as well as in the imagery of our critical mind, matter appears as flickering sparks of energy appearing haphazardly and for a certain interval of time in a coherent, well defined, and lasting pattern on the space-time screen in our consciousness."

EMERGENCE OF ATOMIC ENERGY.

The idea of emergent energy becomes very significant when applied to the energy usually regarded as being "locked up" in the atomic nuclei. According to the current theory an atomic nucleus is built of protons and neutrons, the former having a unit positive electric charge and the latter no charge at all. Both have approximately the same mass. Neutrons do not ordinarily exist very long in free form. They are ejected by the nuclei of the atoms of beryllium, boron, and lithium when bombarded by high-speed alpha particles. Since the neutrons are uncharged, they can easily penetrate the negatively charged electronic envelope of atoms, and occasionally they hit the small nuclei themselves. This ordinarily results in elastic or near elastic collisions, but when the neutrons are moving slowly enough, a capture or other types of modification may take place resulting in the formation of new kinds of nuclei, which usually are unstable. When neutrons hit the nuclei of plutonium or of uranium of atomic weight 235 they are split into two or more parts with the release of several neutrons. If the speed of the neutrons is sufficiently reduced by collisions, they can split other nuclei, additional neutrons are produced, and the transformation then proceeds as a chain reaction with explosive violence. A definite amount of mass equivalent to the released "binding energy" is, directly or indirectly, converted into radiant energy. Like other types of emergent energy, the radiant energy released is quantitatively governed by Einstein's relation, $E = mc^2$, where E now represents the radiant energy and m is the annihilated mass. On account of the enormous size of the factor c^2 the amount of emergent energy is extremely large in proportion to the annihilated mass. The term "emergence of energy" is in this case perfectly natural and appropriately describes the phenomena observed.

An atomic nucleus can be described diagrammatically as a potential field and analytically as a potential function indirectly defining the

probability of the emergence of definite amounts of mass, energy, and charge at a certain place and at a certain time. Such a description is in complete harmony with that previously given for radiation and electrons. In fact, the whole technique used in accomplishing atomic disintegration is based on probability considerations. Atomic nuclei can be regarded as potentialities that can be changed into actualities in the form of observable corpuscles, including photons, the changes being governed by statistical rules. The ideas introduced here are that the probabilities involved are not primarily due to any unpredictable position and motion of the nuclear targets, but to an unpredictable behavior of nuclear fields and to the effect of interaction between such fields. Further, it is assumed that corpuscles are transient, energy carrying indicators of the fine structure of fields and should, when not acting, be replaced by field units inside the nuclei. The inherent instability of nuclear fields is very evident in the case of radio-active nuclei, and it applies also to artificial disintegration. Definite statistical rules or potentialities exist, however, both for atoms and their nuclei, and these potentialities should properly be regarded as representing the only knowledge of "matter in itself" of which we, with a knowledge derived from effects rather than from causes, can properly speak.

The following question has often been asked lately. From where does the energy come that is released in atomic disintegration or fission? A reference to the existence of suddenly released great binding forces inside the nuclei carries us part of the way, but does not tell us anything about the ultimate origin of energy. We may say that the energy was in the form of mass which could be manifested by its effect on inertia and gravity. The elements of matter, e.g. protons, are usually supposed to have existed from "the beginning of time" as a primordial gas. This gas is supposed to have condensed into stars. In the hot interior of the stars atomic energy is released; in the sun largely as a formation of helium from hydrogen. Heavier elements, like uranium, may possibly be formed in the sun from lighter elements, and when the earth, according to prevalent theory, was formed as an offshot from the sun, it retained some of these heavy elements which we now use to furnish us with atomic power. There are many unsolved problems in this connection. As we shall see later, the theory of emergent energy gives us a hint about the ultimate origin of mass and energy, a problem beyond the scope of ordinary physical theories.

EMERGENCE OF ORGANIZED ENERGY.

The energy we have studied so far has been unorganized, that is, the individual emergent elements of mass and energy have appeared at places and at times which do not indicate any regularity other than that imposed by the experimental arrangements. Each individual atom, however, is an organized structure with definite energy levels, and we

can picture this potential energy pattern as existing in a frame work of multi-dimensional space and a one-dimensional, directed time axis. Energy appears and disappears inside this pattern when radiation is absorbed or emitted. This picture is of importance, since it furnishes us with an analogy to what happens on a larger scale when energy emerges in the fluid structures known as living matter.

In living organisms, and in animals in particular, we have a hierarchy of autonomous fields, each with its particular structure and often with its particular function. These fields expand during growth and embryonic development from "sources" of infitesimal size.[1,3] These fields have the power of organizing the chemical substances of which living organisms are built, and biologists therefore call them "fields of organization" or "embryonic fields." Some of their properties can be studied with the aid of a recently developed micro-voltmeter, as has been done at the Medical School of the Yale University.[10] I have used the term "living fields" as a more general term applicable both to the embryonic fields and to the fully developed fields, capable of performing their special functions. There is now almost conclusive proof [3] that such fields really are autonomous, that is, they are not produced by the matter involved.

A living field is a potentiality, like the earth's gravitational field, or a field of electromagnetic radiation. During the development of a living organism mass enters into the cell structure of the living field, which is a complex system of many field units, and the structural properties of the field then become observable. The mass that enters is in this case not elementary particles or definite energy units, but complex molecular aggregates, e.g. fluid protein molecules. If the chemical structure of the molecules is such that they fit into the structure of the living field, which apparently has a great number of characteristics that cannot be directly observed, the moving, fluid molecules are captured, a selective process aptly described as assimilation. The visible result of this process of organization is the formation of a plant or an animal.

A muscle is a living field and represents a potentiality of doing useful work. In order that actual work shall be done, energy must enter the field structure. This energy is in the form of chemical energy, produced by oxidation or splitting of carbohydrates, fats, and proteins. Like a muscular field, a nerve field is a potential and not an actual form of energy, and therefore it can be modified without the expenditure of actual energy. An action of the will, which is not a form of energy, can therefore accomplish changes in its potential structure, and indirectly in the muscular fields to which it is connected, a fact that immediately disposes of an old and very difficult problem. If the load is not too great, the unorganized chemical energy can be converted into organized, mechanical energy (work), and the conversion is in some cases governed by the will. If my will, which does not belong to the

physical world, can influence phenomena in the physical world, it is conceivable that a more general and comprehensive *Cosmic Will* is behind *all* phenomena in nature.

The structure of an animal and its organs is clearly teleological, that is, it serves a useful purpose, and the development is directed towards a well defined end product, not yet realized. It reflects an intelligent planning far beyond that ever done by the human race.

The Second Law of Thermodynamics states that the disorganization (entropy) in a closed system steadily increases. This rule is quite obvious when we have to do with a number of *independent* elements, like the molecules of a gas. The energy produced in a muscle is directly organized by its living field, and the result is coordinated movements of the different parts of the muscle. We can therefore expect that a muscle performs mechanical work in a more efficient way than any ordinary heat engine, because in a heat engine a large part of the energy is rejected as heat at a fairly high temperature.

The fact that the universe is still in an active state indicates that there are forces acting which oppose the tendency towards a general degradation of energy and a consequent "heat death." The theory of emergent energy can be reconciled with Boodin's [11] idea of the universe as a "going concern." In the usual theory the universe is a machine that, once started, runs its predetermined course until completely worn out. In the living world it seems that organization as well as energy enters into and disappears from the physical world, and something similar seems to take place in the inorganic world when the organized structures we call atomic nuclei, atoms, and molecules are formed.

THE ORIGIN OF ENERGY.

I have repeatedly spoken about an emergence of energy, mass, and momentum into the physical frame work of space and time without mentioning the realm from which these entities are supposed to emerge and into which they again submerge. I have pictured the transformation of the extended, potential form of energy into the highly concentrated or corpuscular form as an *emergence* of energy, rather than as a *contraction* of a field element, because the contraction must be *instantaneous*, and such a process can not be regarded as having any *physical* meaning. Further, the emergent energy has properties that cannot all be described in terms of space and time, a fact particularly evident in the case of the so-called "living fields." We are therefore justified in stating that the realm from which energy appears to emerge contains elements not included in our space and time description of physical phenomena, and therefore must be described as existing in *configuration space* rather than in physical space. Since, by definition,[1] all physical phenomena can be expressed in terms of space and time, we shall call the domain mentioned a *non-physical world*. Before describing its

more fundamental properties we shall define its relationship to the empirical science of physics.

The physical world of our experience has three space dimensions and one directed time axis. Together these dimensions form a four-dimensional frame work for description of physical phenomena. The frame work of our empirical physical world can best be defined as an intersubjective world describing space-time structures, as explained in another publication.[1] All evidence points to the fact that this four-dimensional frame work is governed by the invariance expressed in the theory of relativity. Let us now picture this frame work as everywhere contiguous with a non-physical world to which our concepts of space and time are not applicable in their physical sense of expressing the direct results of measurements. To simplify our picture we can limit ourselves to one dimension of space, and our space-time continuum is then an ordinary two-dimensional surface bounded on both sides by the non-physical world. Otherwise the surface is unbounded, but it may be curved and closed like an egg shell, in which case it represents a universe that is finite but unbounded. The properties of this space-time can be investigated by observers using "tools," like yard sticks, clocks, light signals, falling bodies, etc. In certain places the observers find that Euclidean geometry holds, and space-time is said to be "flat." In other places this kind of geometry does not hold, and space-time is said to be "curved," the curvature being defined by a number of coefficients (field potentials).

In the theory of the autonomous field a curvature of space-time is not caused by matter, but is an intrinsic property of the field. The cause of the curvature is supposed to lie in a non-physical world. This is in conformity with our general idea that the origin of a curvature lies in a dimension *external* to a curved surface. The cause of the curvature cannot be matter *as we know it*, that is, as we describe it in terms derived from our sense data and from physical measurements. The relatively simple curvature of inorganic fields is in living fields replaced by an exceedingly complex structure, and the cause of this structure lies, as I have shown in previous publications, in a non-physical world.

Energy, mass, and momentum are probably partial aspects of a more fundamental entity in the universe. They represent primarily a relationship between an external world and us and our consciousness, rather than one between external objects. This is born out by the fact that they cannot be defined in exact terms without reference to an observer, since they all are measured quantities depending upon what we call the motion of an object relative to an observer. When "in transit" they are unobservable and must be represented as being in a diffused form and can be expressed by convenient mathematical symbols rather than by measured data. A realist may claim that they are identical

with their effects, a naive theory which as we now know does not work. In the relativity theory energy and linear momentum are represented as the components of a four-dimensional vector. In the quantum theory the common practice is to use operators to define energy and momentum. Irrespective of what mathematical forms we use, energy, mass, and momentum, and fields of force can always be regarded as potentialities defining the probability as well as the intensity and the quality of events that we can expect to happen under certain conditions. These potentialities, which in quantum mechanics are described as the wave characteristics of corpuscles, must be represented in multi-dimensional configuration space, which does not belong to the physical world of our experience. When used for prediction of the place and time of the emergence of energy, the potentialities must be expressed in terms of measurements in space and time by a particular observer with his instruments, or in the four-dimensional space-time common to all observers. The quantum of action, which is highly significant on the non-physical level of description, but has no recognizable counterpart on the physical level, is, together with some other physically meaningless but intrinsically meaningful characteristics, e.g. psi waves, lost in this transformation, a loss which results in an uncertainty in the predictions and necessitates the use of probability functions. We can hence speak of two types of descriptions needed in the science of physics. One, which we may call *positivistic*, is primitive, gross, and entirely empirical; the other, which we may call *transcendental* goes deeper into the nature of things, is derived from the positivistic one, and is formal, fine-grained, and mathematical. In making predictions of individual events we have learned that we must first go below the physical level and then back to it, and in this process we lose exactness and strict causality. The loss in exactness is quantitatively defined by the size of the quantum of action, a fact expressed by the Principle of Uncertainty.

The problem we are studying can also be analyzed by making a clear distinction between *sapient* knowledge and *sentient* knowledge. Applied to our case the first refers to an objective *description*, and the latter to a subjective *experience* of physical phenomena. All descriptions are inadequate; first, because of the limitations imposed on our knowledge by the specific nature of our sense organs and instruments, and, secondly, because of the particular type of mental equipment we have inherited. An essential feature of our mental idiosyncrasy is that we arrange the elements in the shadow world of our visual sensations in a frame work in space and time. As an example we shall again take the emission of a photon by an atom. On the basis of certain spatial and temporal features of the process, as registered by our special type of mind, we *describe* it in our diagrams and equations as an expanding shell defining the moving wave front of an elementary process associated

with a definite frequency. We *experience* it as a sensation of light of a particular color. In the sapient description a photon is therefore a widely extended entity, in the sentient description it is simply a flash of light. The sensation can, at least in principle, be described as due to the reaction of one particular nerve cell in the retina of one of our eyes.[12] An analysis of the second type of description tells us that the photon is a point smaller than a microscopic nerve cell, and that it contains the total energy involved in the emission process. Evidently we have here two types of physical description, and the difference can be regarded as due to different "perspectives," one describing a diffuse photon in transit, the other a small photon in action. If we apply the same distinction to the elementary particles (corpuscles) we find that a corpuscle is described in transit as an expanding wave and in action as a point. The atom that is hit by the corpuscle is not, like the physicist, an innocent bystander or a clever mathematician, but an actual participant in an interaction process. Like the optic nerve cell previously mentioned, the atom can be said to "experience" a corpuscle in action. As we often do in the case of the lower animals and of living cells, we might describe the process as an "invigoration" of the body of the atom, an invigoration that later makes it possible for the atom to "do something." The mathematical physicist describes the process as an exitation by collision accompanied by an absorption of one or more quanta of action.

In earlier publications [1,13] I have shown that in order to explain the relationship between mind and matter it is necessary to assume the existence of a non-physical world. For instance, the sensation of the color red was assumed to emerge in our consciousness when certain inherited elements (color genes) in the optic ganglia in the retina were stimulated by one means or another, in which case the "redness in the non-physical world" momentarily entered into definite parts of our visual picture. According to this theory there are many types of emergence from the non-physical world into the space-time world, and the two worlds are everywhere contiguous. The similarity between the dualism expressed by the positivistic and the transcendental description of physical phenomena, on the one hand, and the well known dichotomy in the psycho-physical interaction problem, on the other hand, seems to the writer highly significant. In the explanation of both physical and mental phenomena we must picture the emergence of directly experienced qualities (e.g., energy, momentum; colors, pain), into a mental frame work of space and time, a frame work that, as space-time, can be regarded as a particular or partial aspect of the external world directly perceptible to our mind. This analogy is our main justification for the assumption that energy emerges from the same world as do all mental phenomena, as well as the highly organized fields associated with living organisms.

Starting from this assumption one might think that some kind of

information about the non-physical world could be obtained from the mathematical symbolism that has been found so useful in predicting physical phenomena. The only information that has been found so far is that a constant known as the quantum of action exists in the non-physical world and that the concept of size is not applicable to that world. "Time's arrow" seems to have a meaning, but there is no absolute standard for time intervals. Otherwise the information seems to be formal, rather than essential. The non-physical world of theoretical physics is a mathematician's paradise because of his great freedom of expression. He can use a great number of dimensions and he can choose the mathematical tools he likes best, since he does not have to specify the meaning of his symbols and operators. In this connection we recall Eddington's often quoted statement that "a mathematician is never so happy as when he does not know what he is talking about." The only restraint, and it is a serious one, forced on him is that on the physical, that is, the space-time, level the results must agree statistically with the observed facts. It has been found that different methods of description, e.g. wave functions and matrices, give identical results on the physical level. It seems therefore doubtful that we can obtain any information of the more fundamental properties of the non-physical world from theoretical physics.

Sir Richard C. Tute, who in a recent philosophical book [14] has discussed some of the problems here mentioned, has called my attention to the similarity between the theory of emergent energy and of the autonomous field, on the one hand, and Leibniz' theory of monads, on the other hand. The monads are supposed to be indestructible units of activity, and so are in a sense the field units in the theory of the autonomous fields, since they are subject to conservation laws. The energy-carrying corpuscles are the transient, observable *manifestations* of the autonomous field units, and they indicate a particular mode of interaction of the monads and the physical world of our experience. When no interaction occurs, the monads are in theoretical physics represented by wave functions, which describe the wave characteristics of corpuscles. The monads of Leibniz can be regarded as representing a form of sapient description of nature, whereas their manifestations, in the physical world as corpuscles and in the mental world as sensations, feelings, etc., represent a sentient description of nature.

After the theory of emergent energy had been partly developed I learned that Sir James Jeans had previously expressed a very similar idea in a remarkably simple form, well worth repeating here. He writes: [15] "We are thus led conjecturally to think of space and time as a sort of outer surface of nature, like the surface of a deep, flowing stream. The events which affect our senses are like ripples on the surface of this stream, but their origins—the material objects—throw roots deep down into the stream." At another place [16] he writes: ". . . we have no right

to assume that this external world is . . . itself confined within the limits of space and time . . . we must move to some new plane of thought before we can realize that the particles and the waves are shadow pictures of one and the same universe." The present discussion can be regarded as an attempt to provide such a "new plane of thought."

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Coated Fabrics.—Promise of a modest revolution in outdoor sportswear, upholstery, protective clothing and safety garments, drapes, curtains and wall covering materials was seen recently by the Rubber Manufacturers Association in wartime developments which are bringing rapidly to civilian markets a broad and colorful new line of coated fabrics.

"The sudden ending of the war has given the so-called 'World of Tomorrow' coated fabrics to the world today," the association said. "Coaters throughout this division of the rubber manufacturing industry are already in production on a number of amazing lines of such special purpose materials."

"Coating materials now in use include both new and standard rubber and synthetic rubber compounds, oil, pyroxylin and revolutionary synthetic resins, particularly of the polyvinyl chloride and butyral types.

"For many purposes," the association said, "new synthetic rubber and synthetic resin coated materials are expected to supplant other coating materials because of their high resistance to oil and grease. These materials, with rubber coated fabrics which are resistant to many acids and other corrosives, will greatly diversify lines of safety garments and industrial clothing."

Polyvinyl butyral puts an entirely new product on the coated materials market. It was developed as a suitable coating material from the synthetic resin which is used in the center of a safety glass "sandwich" after the Japs cut off rubber supplies and compelled coaters to find new materials. It was used with excellent results in coating millions of yards of jungle or camouflage cloth. Flame-, stain- and water-proof, materials coated with this resin hold great promise in a new line of hunting and fishing wear and for shower curtains and drapes, the association said.

In these respects, it will parallel to some degree the uses of materials coated with the polyvinyl chlorides which had been introduced under various trade names before the war. The latter were coming into increasingly wider uses at the time war needs placed them in the category of critical materials and withdrew them from civilian markets.

These and all other coating materials except natural rubber and GR-I (Butyl rubber) are again available. And natural rubber itself, the original coating material, may well become available in 1946, the association said.

In this connection, it is the feeling of many coaters that there will be no appreciable substitution of new materials for rubber. Both natural and synthetic rubber are expected to hold an important position in the coating field.

Oil coaters, constituting another major branch of the coated materials industry, played an important part in war production of coated fabrics, employing their traditional media in addition to making use of the alkid resins.

By the same token, it is not felt that there will be any widespread displacement of pyroxylins by the synthetic resins. War research telescoped a generation of technical progress in the coating industry into a matter of 44 months and at the same time created broad new markets that the industry expects to serve with both old and new materials, each according to their special properties and the uses to which they are suited, the association said.

R. H. O.

FREDERICK AUGUSTUS GENTH

1820–1893

CHEMIST—MINERALOGIST—COLLECTOR.

BY

W. M. MYERS* AND S. ZERFOSS.†

A complete history of the development of the science of mineralogy in America is yet to be written. We are partially aware of the debt we owe to the early workers in the science but the contributions of a number of them have become obscured by the passage of years. Frederick Augustus Genth stands in the foremost rank of the pioneer mineralogists of America. His contributions in the field of chemical mineralogy are outstanding. The passage of time and the review of his work which has accompanied it have demonstrated repeatedly the extraordinary accuracy of his results and the unrelenting diligence with which he pursued every activity which would advance the knowledge of the minerals of America. His researches served to expand the basic principles of mineralogy and his European background and education supplied him with technical tools possessed by few in the United States in his time. Indeed, Dr. Genth was one of those intellectual bridges that served to introduce to America the accumulated scientific knowledge which was developed by the early workers in chemistry and mineralogy in Germany.

The Genth collections of minerals, books, photographs, notebooks, medals, letters, reprints and scientific apparatus have been established as a memorial to him in the School of Mineral Industries of The Pennsylvania State College through the generosity of the daughters of Dr. Genth. These collections are being preserved as a unit and now form the most prized item in the extensive mineral collections of the School of Mineral Industries. The documents supply a record of accomplishments and personalities active in the science of mineralogy without known equal in the country. The mineral collection was complete for the time during which it was assembled. Its scientific value today is greatly enhanced by the presence of type specimens from original localities.

The significance of this collection and the character and the accomplishments of the man who assembled it are such that it seems desirable to make a permanent record of this unusual contribution to mineralogy.

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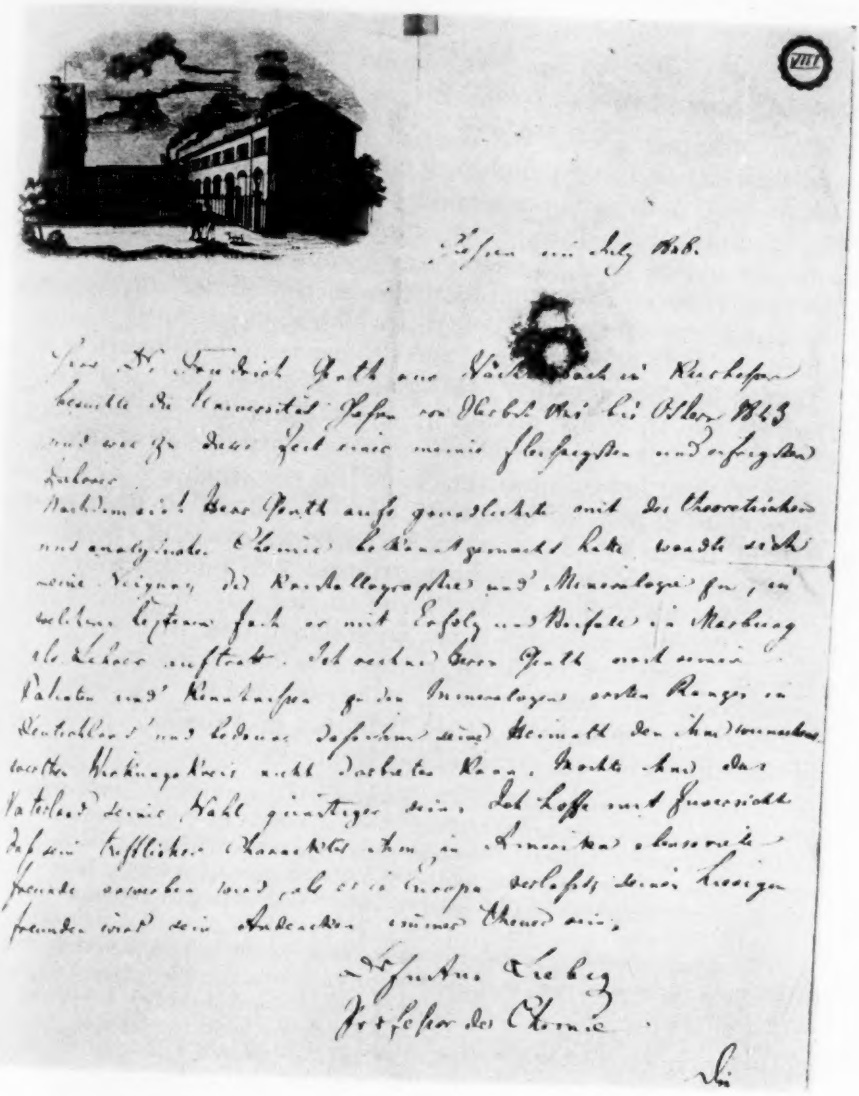
BIOGRAPHY OF FREDERICK AUGUSTUS GENTH.

Friedrich August Ludwig Karl Wilhelm Genth was born in the village of Waechtersbach, Hesse, on May 17, 1820. This is only three years after the death of Werner. He displayed an acute interest in natural history at a very early age. After spending three years in the Hanau Gymnasium he matriculated in the University of Heidelberg in 1839. He there began the systematic study of chemistry, geology, and mineralogy under Gmelin, Blum, and Leonhard. He left Heidelberg in 1841 and became a student in the University of Giessen, concentrating

in chemistry under Fresenius, Kopp, and Liebig. He left Giessen in 1843 due to ill health and then entered the University of Marburg in 1844, studying under Bunsen and Gerling. He thus had the advantage of contact with an eminent group of professors. After obtaining his doctor's degree at Marburg he became Chemical Assistant to Professor Bunsen and later was appointed Privat-Docent in the University. He held this position for three years and in the summer of 1848 sailed for Baltimore. This was a year of unrest in Germany and of migration of many Germans to the United States, who subsequently founded many outstanding American families.

The following letter preserved in the Genth Collection was written for him by his old Professor Justus Liebig. The original is reproduced in the accompanying illustration.



Giessen, July 1848

"Dr. Frederick Genth from Waechtersbach in Hesse-Cassel was a student of the University at Giessen from the autumn of 1841 until the spring of 1843, and was during that time one of my most diligent and industrious pupils.

"After Mr. Genth had made himself most thoroughly acquainted with theoretical and analytical chemistry, he became interested in Crystallography and Mineralogy, in which latter

science he delivered successful lectures at Marburg, which added to his reputation. With reference to talents and knowledge I consider Mr. Genth to be one of the best Mineralogists in Germany and I am sorry that his native country cannot afford him a desirable position. It is to be hoped that he will receive more favor in his adopted country. With confidence I anticipate that his excellent character will make him as many friends in America as he leaves in Europe. His friends here will always entertain a kind remembrance of him."

(signed) Dr. Justus Liebig,
Professor of Chemistry

Translation—Liberata Emmerich.

Soon after his arrival in America he went to Philadelphia and established one of the first analytical laboratories in America. He then spent a short time as Superintendent of Mining operations in North Carolina but returned to Philadelphia in 1850. He reopened his laboratory and devoted his energies to commercial chemistry, research, and the instruction of a few pupils. He soon established correspondence with the leading scientists of America which was continued throughout his life. In 1872 he was offered the Professorship of Chemistry in the University of Pennsylvania. He finally accepted this offer with the understanding that his private practice could be carried on. He continued his connection with the University until the fall of 1888, when he left and returned to consulting work and research.

The amazing part of the career of Dr. Genth is that while engaged in consulting work with the commercial applications of chemistry he found time to make substantial contributions to fundamental science. Among the outstanding researches he carried out were those on the complex cobalt-amine compounds, in collaboration with Dr. Wolcott Gibbs, corundum and its alteration products, meteorites, telluride compounds, phosphates and fertilizers, and rare minerals.

Edgar F. Smith in his book, "Chemistry in America," presents the following entertaining account of Genth at work.

"The writer met J. Lawrence Smith in the laboratory of Genth (1879). It was his privilege to observe these two eminent and brilliant chemists at work. They had differed on a point in the analysis of a complex silicate and, rather than cover valuable pages of some journal with their differences, occupying space that could be better used, they determined to settle the point at issue by experimental demonstrations made in each other's company. In this particular case Genth was in the right.

"It was a further privilege of the writer to see Gibbs, Genth, and Smith working amicably and cheerfully in the same room over problems which greatly interested them. Some of the difficult points in the analytical study of the cobaltamines were settled by Gibbs and Genth with the writer a very silent but much interested observer and auditor of the work and remarks of these pioneers.

"Smith appeared in the laboratory of the University where the writer was an assistant. He was then short and stout of figure. His hair was heavy, thick, quite gray, parted on one side, rather long and brushed back. He wore spectacles which rested on the end of his nose. On learning that the writer was endeavoring to procure a compound ether by heating the silver salt of an organic acid with ethyl iodide, Smith, having seated himself on a high stool, remarked "that is a new method to me." On several occasions the writer enjoyed hearing from Smith the story of his study of the rare earths and, in particular, his experiences in unravelling the composition of samarskite, in which he was especially interested.

"The reader will pardon this personal digression on the part of the writer, but to him it has always seemed as if there could not be too much credit given Genth, Gibbs, and J. Lawrence Smith for the admirable contributions they made to the development of chemical science in the United States."

Chemistry in America. By Edgar F. Smith. D. Appleton and Co., New York. 1914. pp. 259–261.

The period in which Dr. Genth lived was one characterized by an intense interest in pure discovery, the discovery of new lands, new rocks, new minerals, and new processes. The interest in taxonomy in the

TABLE 1

List of New Minerals Reported by Genth

Mineral Name	Composition*	Year Reported
Barnhardtite	Cu, Fe, sulfide	1855
Whitneyite	Arsenical Copper	1859
† Melonite	$NiTe_2$	1868
† Calaverite	$AuTe_2$	1868
† Cosalite	$Pb_2Bi_2S_5$	1868
† Schirmerite	$PbAg_4Bi_4S_9$	1874
† Coloradoite	HgTe	1873
Nickel Gymnite (Genthite)	Hydrated Mg-silicates with Ni	1851
† Montanite	$Bi_2O_5TeO_32H_2O$	1868
† Kerrite † Maconite † Willcoxite † Dudleyite (after Margarite)	Vermiculites	187
† Psittacinite	Var. Descloizite	1876
Magnolite Ferrotellurite	Te minerals	1877
† Endlichite	Var. Vanadinite	1885
† Lansfordite	$MgCO_3\ 5H_2O$	1888
† Nesquehonite	$MgCO_3\ 3H_2O$	1890
† Phosphuranylite	a Uranyl—phosphate	1879
† Penfieldite	$Pb(OH)_2 \cdot 3PbCl_2$	1892

† Mineral species or varieties recognized at present.

* Formulas taken from Dana's System, Vol. 1, 7th Edition, 1944, or from Dana's textbook of Mineralogy, 4th Edition, 1926.

natural sciences was still acute and chemists were constantly on the search of a new mineral species or trying to certify a new meteorite. Dr. Genth was particularly happy when engaged in the identification of a new mineral species. The list of new minerals (23) reported in his memoir in the National Academy of Sciences is given in the accompanying table. Subsequent investigations have indicated not all of this list are true species. Those marked with † can be found in our present mineralogy. If we consider that his only tool of identification was chemical analysis the fact that some of the minerals were not true

species is not remarkable. The total of accepted species is a very substantial contribution to be made by one investigator.

Dr. Genth served the Commonwealth of Pennsylvania, being Chief Chemist and Mineralogist to the Second Geological Survey. He also was appointed Chemist to the Board of Agriculture where his knowledge of analytical chemistry was of great value in solving agricultural problems, particularly those connected with fertilizers.

Dr. Genth died in Philadelphia, February 2, 1893, in his seventy-third year at the end of a lifetime unsparingly devoted to the advancement of science. His contributions to the literature of chemistry and mineralogy total one hundred and two.

THE GENTH CORRESPONDENCE.

The Genth correspondence consists of over eight hundred letters, practically all of which are holographs. The list of correspondents is a "Who's Who" of mineralogy of the world. Over two hundred of the letters are in German, a few in French, and six hundred in English. This material will supply a rich mine of data to the research student. Among the European correspondence, to mention only a few, we find such names as Zirkel, Ahfeld, Bronn, Bertrand, Hausmann, Groth, Weisbach, Kolbe, Breithaupt, Gadolin, and Des Cloizeau.

Among the English letters we find such familiar names as Louis Agassiz, who sometimes wrote in German, Wolcott Gibbs, George L. English, George F. Kunz, William E. Hidden, W. C. Kerr, J. A. Holmes, R. A. F. Penrose, Jr., Charles E. Munroe, Ira Remsen, Edgar F. Smith, F. W. Clarke, J. Lawrence Smith, A. C. Hamlin, Joseph Henry, T. Sterry Hunt, J. P. Lesley, A. W. Winchell, C. F. Chandler, N. S. Shaler, Joseph Leidy, Franklin Bache, and S. P. Langley.

Of special interest to the mineralogist is the correspondence from James D. Dana, consisting of 45 letters, dated from 1853 to 1892; from George J. Brush, 36 letters, dated from 1854 to 1889; from Samuel L. Penfield, 39 letters, dated from 1888 to 1893; and from Benjamin Silliman, Jr., 48 letters, dated from 1853 to 1887.

THE GENTH MINERAL COLLECTION.

Dr. Genth was an enthusiastic and persistent collector of mineral specimens. He acquired material by purchase, exchange, and personal collection for which he had exceptional opportunity due to his extensive professional contacts. For example, an acquaintance in Arizona sent him a number of specimens of the mineral vanadinite. In the course of the correspondence the acquaintance expressed the wish that Genth would name any new mineral found in the material after Endlich. Genth did name an arsenic rich vanadinite—Endlichite, from New Mexico and quite naturally the mineral specimens thus acquired were included in his collection.

His collection of more than 5000 cataloged specimens is typical of the "mineral cabinet" of the nineteenth century. The specimens average about 3 inches in largest dimension and are arranged in separate trays with a carefully hand written numbered label in each tray. Genth placed the whole collection in six specially built mahogany cases.

His collection was practically complete for its time and as a scientific study collection must have had few private rivals for its period. A species is rarely represented by less than two localities and in the case of the American minerals the most important localities are represented. Since the collection is that of a scientist rather than a mere collector and value of the specimens lies in the completeness of labelling and variety of localities rather than in the size or superficial beauty. That is not to suggest that some of the specimens are not beautiful items. There are numerous well formed crystals, crystal groups, or polished slabs in the collection that would attract the artistically interested collector.

Among the outstanding and irreplaceable specimens are seventy meteorites, fifty-eight of which are from finds made in North America and in addition seven specimens of terrestrial iron. Nesquehonite and Lansfordite, two Pennsylvania minerals established by Genth and Penfield, are represented by nineteen specimens. Corundum and its alteration products, material on which Genth was an authority, complete a suite of 265 representative specimens. The garnet family is illustrated with 128 specimens. Pennsylvania minerals are exceptionally well represented with specimens from the Gap nickel locality and many representatives from the pegmatites of the Brandywine district. Very few thin-sections are to be found in the collection but it must be remembered that Genth was a chemist and not a petrographer. The full value of this collection will not be realized fully until more work has been done with it. Its service to science will increase with the years. The most remarkable specimen is the fragment of a well formed crystal of Genthelvite from W. Cheyenne Canyon, El Paso Co., Colorado. As far as known this is unique and no similar material is known to exist.

The example of Dr. Genth in his devotion to science and the presence of his collections continue to serve as an inspiration to students of mineralogy at The Pennsylvania State College.

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3. Chabazit von Annerod bei Giessen.
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5. Speisskobalt von Riechelsdorf.
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1852.
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1852.
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1852.–1853. 24. On a probably new element with Iridosmine and Platinum, in California. Proc. Phila. Ac. Nat. Sci., vi, pp. 209, 210; Am. Jour. Sci., xv, p. 246.

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Gray copper.
Apophyllite.
Allanite.

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Owenite.
Kaemmererite.
Emerald-nickel.

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Pyrophyllite.
Chrysotile.
Scolecite.
Owenite (identical with Thuringite).

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Tetradymite.
Bismuthine.
Aciculite.
Barnhardtite, a new mineral.
Gray Copper.
Geocronite.
Garnet.
Allanite.
Tungstates of North Carolina.
Scorodite.
Wavellite.

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Bismuthine.
Harrisite (Shepard), a pseudomorph of copper glance after galena.
Cantonite (Pratt), a pseudomorph of covellite after galena.
Linnaeite.
Enargite.
Coracite (Leconte) is Pitchblende.
Epistilbite.
Shepard's Plumboresinite is Cyanosite.
Cherokine (Shepard) is Pyromorphite.
Vivianite.
Wavellite.
Dufrenite.
Hitchcockite.
Lanthanite.
Bismuthite.

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1859. 43. Contributions to Mineralogy. Am. Jour. Sci. (2), xxvii, p. 400.
Whitneyite, a new mineral.

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Native iron.
Native bismuth.
Whitneyite.
Bernhardtite.
Gersdorffite.
Molybdate of Iron (Owen) is Molybdite.
Albite.
Ripidolite.
Pholerite.
Scheelite.
Rhombic tungstate of lime.
Wolfram.
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Gold, pseudomorphous after aikinite.
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Arsenides of Copper, Domeykite, Algodonite, Whitneyite.
Copper glance, pseudomorphous after galena.
Millerite.
Proustite.
Automolite.
Pyrope.
Lime-Epidote.
Leopardite, a true prophyry.
Staurolite.
Serpentine.
Kerolite.
Monazite.
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2. American Tellurium Minerals.
Petzite and Hessite.
Altaite.
Native Tellurium.
Melonite, a new mineral.
Calaverite, a new mineral.
Tetradymite.
Montanite, a new mineral.
3. Barnhardtite from Arizona.
4. Cosalite, a new mineral.
5. Boulangerite.
6. Tetrahedrite from Arizona.
7. Brochantite.

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Altaite.
Hessite.
Petzite.
Sylvanite.
Calaverite.
Tellurate of Copper and Lead.
Bismuthine.
Schirmerite, a new mineral.

1875. 61. Preliminary Report on the Mineralogy of Pennsylvania, "B," of the Second Geological Survey of Pennsylvania, 206 pages.

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Psittacinite, a new mineral.

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Native Tellurium.
Hessite.
Coloradoite, a new mineral.
Calaverite.
Tellurite.
Magnolite, a new mineral.
Ferrotellurite, a new mineral.
Roscoelite.
Green Mineral from Colorado (Aluminous Roscoelite).
Volborthite.

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Gummite.
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1881. 73. Minerals and Mineral Localities of North Carolina, by F. A. Genth (and W. C. Kerr). Chapter 1 of volume ii of Geology of North Carolina, 1881, 122 pages.

1881. 74. In "Egyptian Obelisks," by Henry Gorringe:

Analysis of the Plagioclase from the Granite of the obelisk, p. 162.
Analysis of the Cement attached to the Pyramidion obelisk, pp. 169, 170.
Analysis of the Bronze from the Crabs of the obelisk, p. 173.
Analysis of the paints on images about 4,000 years old; Yellow and Gilt paint, Black paint, Red paint, pp. 173–175.

1882. 75. On Ensilage, in Sixth Annual Report of the Pennsylvania Board of Agriculture for 1882, pp. 107–109.

1882. 76. Analyses of Fertilizers, Annual Report of the Pennsylvania Board of Agriculture for 1882, pp. 392–394, Nos. 183–301.

1882. 77. Analysis of the Emerald-green Spodumene, "Hiddenite," from North Carolina. Am. Jour. Sci. (3), xxiii, p. 68.

1882. 78. Contributions to Mineralogy. Proc. Am. Phil. Soc., August 18, 1882.

I. 1. Corundum altered into Spinel.
2. Corundum altered into Zoisite.
3. Corundum altered into Feldspar and Mica.
4. Corundum altered into Margarite.
5. Corundum altered into Fibrolite.
6. Corundum altered into Cyanite.
7. When were the corundum alterations formed?

II. Alteration of Orthoclase into Albite.
III. Alteration of Talc into Anthophyllite.
IV. Talc, pseudomorph after Magnetite.
V. Gahnite from Mitchell county, N. C.; from Cotopaxi, Col.; by H. F. Keller.
VI. Rutile and Zircon from the Itacolumite of Edge Hill, Bucks county, Pa.
VII. Sphalerite and Prehnite from Cornwall, Lebanon county, Pa.
VIII. Pyrophyllite in Anthracite.
IX. Beryl from Alexander county, N. C.
X. Niccolite from Colorado.
XI. Artificial Alisonite.

1883. 79. On Robert Wilhelm Bunsen in Encyclopaedia Americana, i, pp. 675–677.

1883. 80. Analyses of Fertilizers in Seventh Annual Report of Pennsylvania Board of Agriculture for 1883, pp. 365–374, Nos. 300–518 and 86–295.

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1885. 82. On the Vanadates and Iodyrite from Lake Valley, N. M., by F. A. Genth and Gerhard vom Rath. Am. Phil. Soc., April 17, 1885, xxii, A, pp. 363–375.

Vanadinite. Descloizite.
Endlichite, a new species Iodyrite.

1885. 83. Über Vanadate und Jodsilber von Lake Valley, N. M., von F. A. Genth and G. vom. Rath. Groth's Zeitschrift, x, 6, pp. 458–487.

1885. 84. Contributions to Mineralogy. Proc. Am. Phil. Soc., October 2, 1885, xxiii, pp. 30–47.

1. Tin and associated minerals.
2. Joseite and Tetradymite.
3. Seleniferous Galenobismutite.
4. Argentobismutite.
5. Cosalite.
6. Schirmerite and Beegerite.
7. Tetrahedrite—Sylvanite.
8. Polybasite.
9. Arsenopyrite and Scorodite.
10. Alteration of Magnesian Limestones from Berks County, Pa.
11. Ilmenite from Carter's Mines, N. C.; Oligoclase.
12. Topaz from Stoneham, Me.
13. Orthoclase from French Creek, Chester County, Pa.
14. Muscovite after Nephelite.
15. Stilpnomelane pseudomorphs—Ankerite.
16. Calamine.
17. Titanite.
18. Vanadinite.
19. Annabergite.
20. Dr. Clemens Winkler and Herderite.

1886. 85. Analysis of pseudomorph from Magnet Cove, Ark., in Geo. F. Kunz Mineralogical Notes. Am. Jour. Sci. (3), xxxi, p. 74, January, 1886.

1886. 86. On an undescribed meteoric Iron from East Tennessee, with two photographic plates. Proc. Ac. Nat. Sci., December 28, 1886.

1887. 87. Contributions to Mineralogy, No. 24. Proc. Am. Phil. Soc., March 18, 1887, with 1 phototype plate and 3 wood cuts.

I. Occurrence of Tin ores in Mexico.
1. On Cassiterite—a, C. red variety; b, C. yellow variety; c, C. pseudomorphs after hematite; d, C. pseudomorphs after magnetite.
2. Hematite.
3. Mimetite and M. pseudomorphs after anglesite.

II. Vanadinite and Descloizite.
III. Pyrite pseudomorphous after pyrrhotite.
IV. Hessite.
V. Tapalite.
VI. Allanite.
VII. Willemite.
VIII. Hisingerite pseudomorphous after calcite.

1888. 88. On Lansfordite, a new mineral. Groth's Zeitschrift. xiv, 255–6.

1889. 89. On Two Minerals from Delaware County, Pa. Proc. Ac. Nat. Sci., 1889, pp. 50–52, with one wood cut.
1. Gahnite.
2. Columbite.

1889. 90. Contributions to Mineralogy, No. 44. Am. Jour. Sci. (3), September, xxxviii, pp 198–203.
1. Gadolinite from Texas.
2. Cacoclasite.
3. Monazite from Villeneuve, Canada.

1890. 91. Jarosite from Utah. Am. Jour. Sci. (3), xxxix, p. 73, January, 1890.

1890. 92. Contributions to Mineralogy, No. 46. Am. Jour. Sci., xxxix, pp. 47–50.
On a new occurrence of corundum in Patrick County, Va.

Corundum.	Muscovite.
Andalusite.	Margarite in part.
Cyanite and Rhaetizite Chloritoid.	

1890. 93. On Lansfordite, Nesquehonite, and Pseudomorphs of Nesquehonite, after Lansfordite. By F. A. Genth and S. L. Penfield. Am. Jour. Sci., xxxix, pp. 121–137, February, 1890.

1890. 94. Contributions to Mineralogy, No. 48. Am. Jour. Sci., xl, pp. 114–120.
1. Tetradymite.
2. Pyrite.
3. Quartz, pseudomorphous after Stibnite.
4. Gold in Turquois from Los Cerillos, N. M.
5. Zircon.
6. Scapolite.
7. Garnet.
8. Titaniferous Garnet.
9. Allanite.
10. Lettsomite from Arizona and Utah

1890. 95. Contributions to Mineralogy, No. 49. With crystallographic notes by S. L. Penfield. Am. Jour. Sci., xl, pp. 199–207.
1. Amarantite.
2. Sideronatrite.
3. Ferronatrite.
4. Utahite.
5. Picropharmocolite from Joplin, Mo.
6. Pitticite.

7. The so-called Gibbsite from Chester County, Pa., a phosphate.
8. Atacamite.

1891. 96. Contributions to Mineralogy, No. 50. With crystallographic notes by S. L. Penfield and L. V. Pirsson. Am. Jour. Sci., May, 1891, xli, pp. 394–400.
1. Three new varieties of Axinite; a, from Franklin, N. J.; b, Guadalcazar, Mexico; c, McKay's Brook, Northumberland County, N. S.
2. Eudialyte from Magnet Cove, Ark.
3. Titanite from Magnet Cove, Ark.
4. Monticellite from Magnet Cove, Ark.

1891. 97. Contributions to Mineralogy, No. 51. Am. Jour. Sci., May, 1891 (3), xli, pp. 401–403.
1. Aguilarite, a new species.
2. Seleniferous Bismuthinite and Guanajuatite.

1891. 98. Minerals of North Carolina. Bulletin No. 74, U. S. Geological Survey.

1891. 99. Contributions to Mineralogy, No. 52. By F. A. Genth, with crystallographic notes by S. L. Penfield. Am. Jour. Sci., xliii, pp. 184–189.
1. Hübnerite.
2. Hessite from Mexico.
3. Bismutite.
4. Natrolite.

1891. 100. On Penfieldite, a new mineral, No. 53, September, 1892. Am. Jour. Sci., xliv, p. 260 (No. 53).

1891. 101. Contributions to Mineralogy, No. 54, November, 1892. Am. Jour. Sci., xliv, pp. 381–389. With crystallographic notes by S. L. Penfield.
1. Aguilarite.
2. Metacinnabarite.
3. Löllingite.
4. Rutile.
5. Quartz resulting from the alteration of Orthoclase, from W. Cheyenne.
6. Danalite.
7. Yttrium-Calcium Fluoride.
8. Altered Zircon or Cyrtolite.
9. Lepidolite.
10. Fuchsite.

1891. 102. On Anglesite, associated with Bolëite, No. 55, January, 1893, Am. Jour. Sci., xlv, pp. 32–33.

NEW COSMIC RAY RADIOSONDE TECHNIQUES.

BY

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I. INTRODUCTION.

For the first time since the start of the war, a balloon flight was launched, as a part of our cosmic-ray program. In this flight, more complex apparatus was required than had heretofore been necessary and a considerably larger number of balloons was used than ever before. A number of new techniques were developed, which it is the purpose of this article to describe, in the hope that some of them will be found useful by other persons engaged in conducting experiments in the upper atmosphere.

The cosmic-ray measuring instrument was carried aloft by a cluster of as many small balloons as were required to sustain its weight and give it free lift. The instrument included a small radio transmitter and suitable arrangements for keying this transmitter in a manner to signal the quantities which the instrument had measured. The radiosonde transmitted the data which it had measured, automatically, by short wave radio to a receiving station on the ground. In this manner, the information was known at the ground station at the same instant that it was measured in the stratosphere, and the delays and uncertainties in recovering the instrument were avoided. Recovery became of secondary importance, for the data were known without it. Recovery is a geographical problem. Flights launched from the eastern United States tend to drift out over the Atlantic. In our cosmic-ray flight program, during the past nine years, twenty-six flights have been made from stations in the New York and Philadelphia area, of which only twelve have been recovered and of these twelve, three instruments came down in salt water and were rendered electrically useless by corrosion.

A complete survey of the available techniques of radiosonde instrumentation was made some years ago, and appeared in the pages of this journal.[1] In this paper it was pointed out that the system of interrupting the emitted signal was especially adaptable to the transmission of cosmic-ray intelligence. Essentially, a series of dots and dashes of various lengths and spacings was emitted. The length of the signal, i.e., whether it was a dot, a short dash, or a longer dash, told

[1] "The Radiosonde; the Stratosphere Laboratory." E. T. Clarke and S. A. Korff, *Jour. Franklin Inst.*, **232**, 217 (1941).

which quantity was being transmitted, while the number of such signals per unit time indicated the magnitude of the quantity being measured. Alternatively, the time-interval between the emission of a signal and the emission of a reference signal may indicate the magnitude of the quantity being studied. It is the purpose of the present article to describe the details of the techniques used to accomplish the relaying of the several simultaneous measurements.

The purpose of the particular flight to be described, was to measure the energy-distribution of the neutrons produced by the cosmic radiation in the free atmosphere. The details of the measurements and of their interpretation have been published elsewhere,[2] and what we will discuss here is not the energy distribution of the neutrons but the general methods useful for rendering such data transmissible and for receiving and interpreting the signals. These techniques can be adapted to the transmission of any measurements whatever which may be required from the upper atmosphere, if these quantities can be measured by any device capable of either giving a pointer-indication or a set of impulses whose time sequence is a measure of the quantity. These techniques are readily adaptable to the measurement of solar ultraviolet, ozone, ionization, temperature, pressure, humidity, conductivity, and many other quantities.

II. THE NEW INSTRUMENT.

(a) Overall Description.

In order to determine the energy-distribution of cosmic-ray neutrons, the counting-rate of a neutron counter with and without several different shields had to be determined. The instrument, therefore, had to have a shield selecting and changing mechanism. This mechanism caused one of three shields to slide over the counter for a predetermined time interval, then removed this shield and replaced it with a second shield. The counter and three cylindrical shields were all mounted with their long dimensions vertical. The shields were all coaxial and moved one within the other. The cycle of events allowed shield No. 1 to be in place for a definite time. Then this was removed and the counter was unshielded for a similar time. Then shield No. 2 was selected, the events were repeated and finally shield No. 3 was selected. The cycle was then repeated in the same sequence.

The counter was at all times connected to a conventional amplifier circuit. This circuit sent a pulse to the grid of a radio oscillator every time a burst of ionization of the proper size occurred in the counter. The oscillator was in continuous operation and the arrival of the pulse lowered the grid voltage so that the oscillator did not radiate for an instant. The oscillator was also deactivated when shield No. 1 was

[2] S. A. Korff and B. Hamermesh, *Phys. Rev.*, **69**, 155 (1946).

moved. This was done to give a reference point in the cycle of shield motions.

In addition to transmitting the above information, the oscillator was also activated by a baro-thermograph of the Olland [1] type. The pressure enabled the altitude corresponding to any given cosmic-ray signal to be known.

(b) The Shield Drive Mechanism.

Each of the shields was attached to a chain which went to the top of an aluminum framework which held the entire apparatus. Each chain then passed over a separate sprocket gear which had a clutch gear on one side. The chains were then attached to separate guided counterweights.

The three combination sprocket-clutch gears were mounted on the same steel axle on the top of the apparatus. This shaft could be rotated in either direction, i.e., so as to raise or lower the shields whenever the shield driving motor was activated. The three sprocket-clutch gears would idle on their common axle unless one of a set of clutch trip magnets was energized. The gear corresponding to that magnet would then rotate with the axle on the next activation of the shield driving motor.

The selection of the shields and the activation of the shield driving motor was accomplished (see Fig. 1) by having a small motor (operated by one dry cell) turn two separate gears. One of these was the shield selector which would engage each of the three clutch release magnets once, each time it revolved. The second gear was a shield timer which would close the circuit to the shield driving motor twice during a single revolution; once to lower a shield and the second time to raise the same shield. The shield timing gear rotated at 3 times the rate of rotation of the shield selecting gear.

The cycle of events was as follows. The three shields were initially above the counter, i.e., the counter was unshielded. The small timing motor was started rotating. Upon the activation of the clutch trip magnet of shield No. 1, the sprocket-clutch gear corresponding to shield No. 1 would be pulled up by a spring against a clutch gear fixed to the common shaft. When the shield timing gear made its next contact the shield lifting motor would begin to rotate the common shaft. The sprocket-clutch gear corresponding to shield No. 1 would revolve with the shaft whereas those corresponding to shields Nos. 2 and 3 would idle on the rotating shaft. Shield No. 1 would thus be lowered over the neutron counter and its corresponding counterweight would be raised. A limit switch near the end of the path of the moving counterweight was opened when the weight had moved the proper distance.

The above shield would remain over the counter until the next contact of the shield timer was made. The motor would then start and

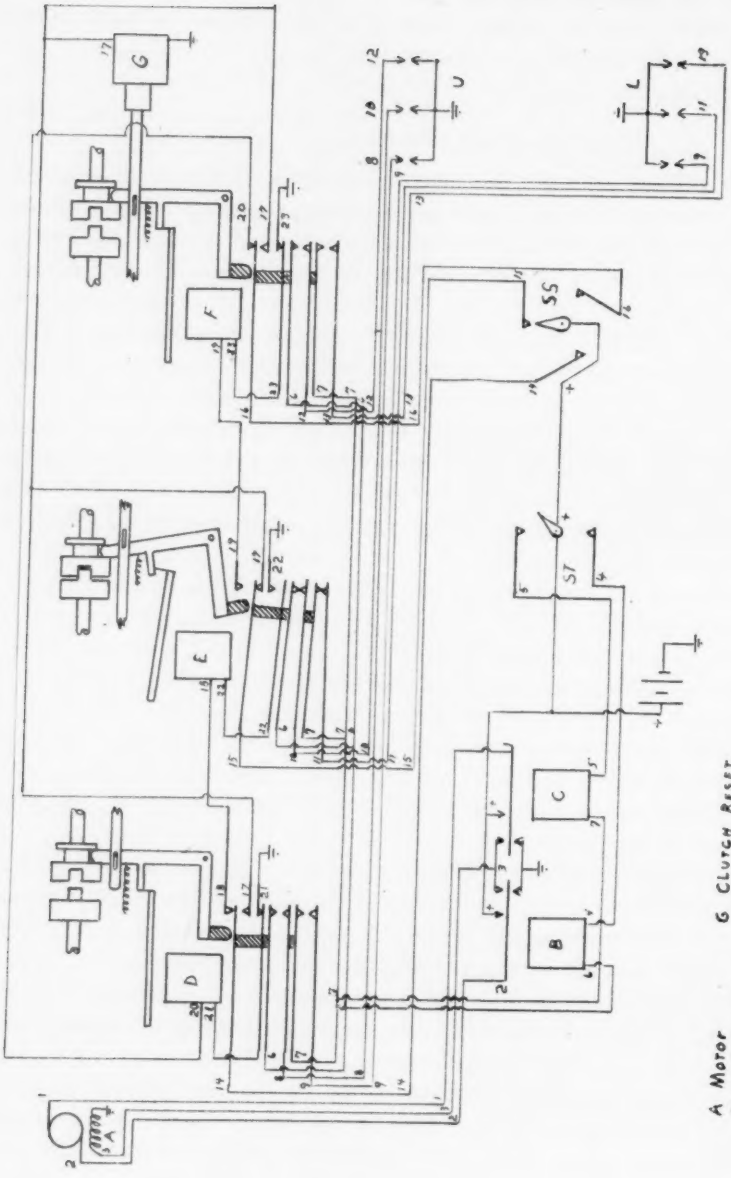

FIG. 1.—Shield selector and drive mechanism and circuit.

would turn the common shaft in such a direction as to raise shield No. 1. The counter would then be unshielded.

Upon the next contact of the shield selector, the sprocket gear of shield No. 1 would be released by the activation of the clutch reset solenoid at which time electric contact would be made so as to activate the clutch trip of shield No. 2. Shield No. 2 would be lowered and then raised and finally shield No. 3 would be handled similarly. The whole cycle would then be repeated.

The solenoids were activated only momentarily to avoid battery drain. This was done by use of a mechanism which latched the clutches into the "open" position. Upon release of the latch a spring would draw the clutch into the "closed" position. The movement of the clutch lever opens the ground connection to the clutch trip magnet (contacts DG, EG, and FG, Fig. 1.). It also transfers the energy from the reset solenoid to the next clutch release magnet. The above transfer would not result in any action in the next shield circuit until the next contact of the shield selector.

The above principles could be used to design an apparatus that would move any number of shields. However, the mechanical problem of the support of the inner shields and the counter itself becomes very complicated with even three shields.

(c) The Amplifier Circuit.

The pulses arriving on the central wire of the counter were fed into the amplifier shown diagramatically in Fig. 2. This circuit amplified the small pulse from the counter until it was large enough to deactivate the transmitting system. In this way, the arrival of a neutron (or a heavily ionizing particle) in the counter would result in a short interval of time in which no radiation was emitted by the oscillator. The length of this interval was determined by the circuit constants in the multivibrator portion of the amplifier circuit, i.e., the second and third 1N5 tubes. A length 0.25 second was chosen so that the recorded signal resulting from a counter pulse could be unambiguously distinguished from any other recorded signal, i.e., temperature, pressure or reference signals, and also be long enough to operate the recording system positively.

(d) The Transmitting Circuit.

The transmitter used is shown in Fig. 3 (built by M. Sumi of the University of Chicago), and is of the push-pull type employing a twin triode type 3A5, similar to those used in radiosondes. The carrier wave was modulated by the output of a phase-shift oscillator shown in Fig. 3 (built by M. Ticho of the University of Chicago), causing the emission of a 2,000 cycle signal. This audio signal was heard at the receiver and intelligence was signalled by interruptions of the audible

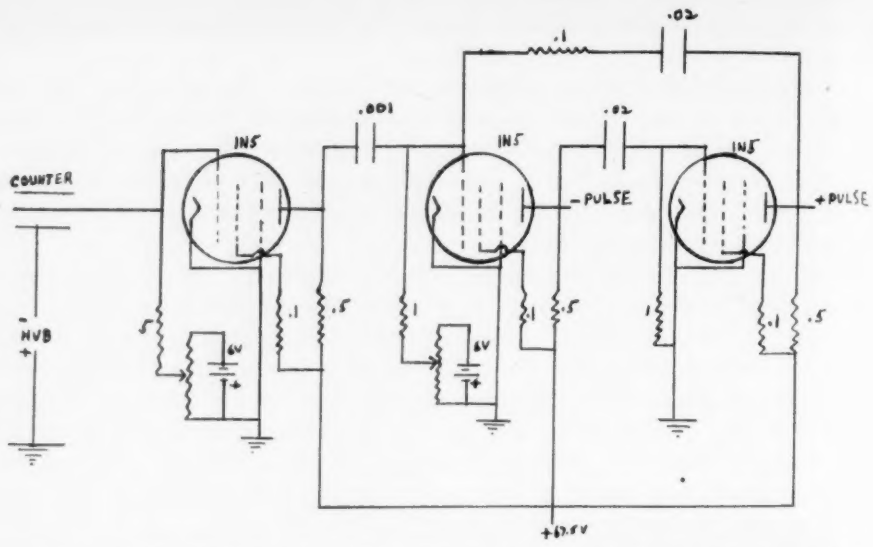

FIG. 2. Pulse amplifier used in flight to convert counter discharges into keying pulses. HVB is high voltage battery, in this case about 1800 volts. Resistances in megohms, capacities in microfarads. Either positive or negative pulses can be obtained from this circuit, as indicated.

note. The continuous audio note is helpful in enabling the operator to tune the receiver readily to the emitted signal.

(e) The Receiving Circuit.

The basic receiving element was a Hallicrafters SX28A receiver. In order to have the receiver operate a pen recorder [1] the coupling

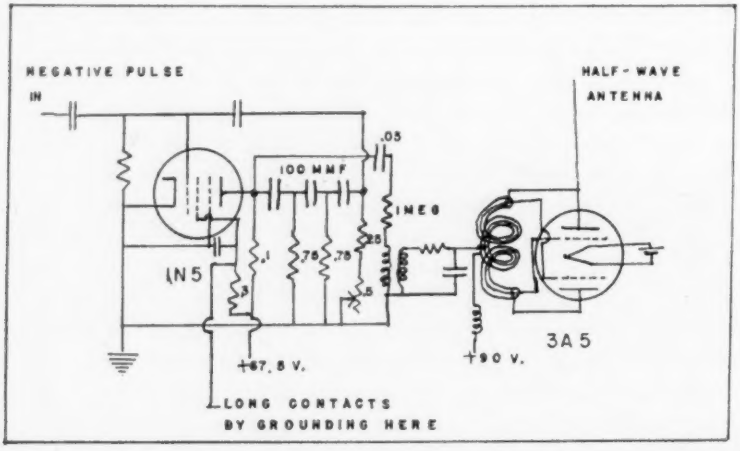

FIG. 3. Phase-shift oscillator for producing audio note to modulate transmitting oscillator. Negative pulse causes suppression of note. Oscillator tank circuit consists of three turns of copper tube with grid coil inside. Capacities in microfarads, resistances in megohms.

circuit shown in Fig. 4 was used. The output of the Hallicrafters was amplified by the first two tubes shown and then rectified by the diode. A potential developed by the diode was applied to the grid of a thyratron, which in turn drove the pen of the recorder. Extinction of the thyratron, was accomplished by operating its plate on A.C., thus causing the discharge to terminate every half-cycle. As long as intelligence was being transmitted and the audio note was absent, the diode kept the thyratron grid positive and the discharge continued. The discharge ceased on the half cycle immediately following the return of the audio note.

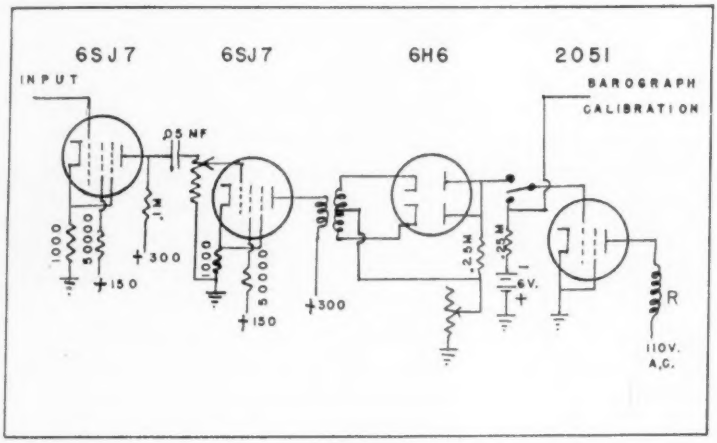

FIG. 4. Recording circuit. The input from the receiver is fed into the first 6SJ7, and the 2051 drives the Recording pen R. Resistances in ohms, M for Megohm, capacities in microfarads. Same circuit is used in calibrating the barograph before flight. The barograph contacts ground the indicated point on the grid of the last tube.

(f) Miscellaneous Features.

The recorder consisted of a Western Electric relay of type G-26 to the armature of which a pen was attached. The pen wrote on ticker tape pulled by a small synchronous motor, and has been described in the previous article on this subject.[1] Positive action could readily be secured on a change of current from 10 to 15 milliamperes through the relay. This current was supplied by the thyratron quite satisfactorily.

The barograph was of the Olland type, and has been described in detail elsewhere.[1] It signalled the pressure with an accuracy which increased with elevation, and also measured the temperature of the instrument. The external air temperature was not required and was not determined in this test.

The shield position was signalled by a sliding arm attached to one of the shields which rubbed against a contact bar while the shield was in motion. By wrapping Scotch tape around the bar at intervals, a

coded signal could be emitted which told the operator which shield was moving and in what direction.

The instrument was, as is our custom, wrapped in a double layer of cellophane during the flight so that the batteries and other parts would be kept from freezing in the stratosphere. This "greenhouse effect" has been found to be effective and it maintained satisfactory internal instrument-temperatures throughout the flight.

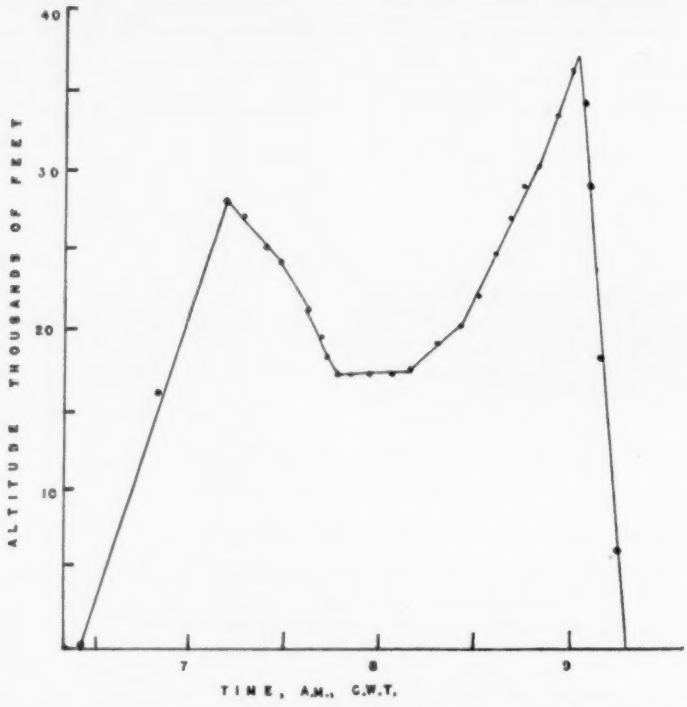

FIG. 5. The altitude-time curve observed in flight 27. One cluster of balloons burst shortly after 7, and the flight began to pick up solar superheat at 7.30 for a second rise. A second cluster of six balloons burst at 9. Observed points from radiobarograph record.

III. FLIGHT EXPERIENCE.

(a) Altitude-time Curve.

The instrument used in Flight 27 weighed 119 pounds including rigging. The flight was carried by 67 balloons of the 350 gram size, each filled to give a lift of 2.6 pounds. The total static upward pull was therefore 174 pounds, and the net free lift was 55 pounds. The flight was launched at 6:27 A.M., C.W.T., on September 7, 1945 from the University of Chicago (Stagg) football field, the time being selected as that at which minimum ground winds were expected. The curve of altitude as a function of time is shown in Fig. 5. It will be noted that the original rate of ascent was 600 feet per minute which was maintained

until 7:10 A.M. at which time a cluster of balloons burst. The instrument then started descending at about 400 feet per minute. As the flight descended it entered the warmer air, and the rising sun at this time caused appreciable heat-gain in the balloons. The flight ceased descending, remained at a level of 16,000 feet for about half an hour, and then started to rise. It rose slowly at first, and then more and more rapidly, until it reached a maximum altitude of 40,000 feet at 9:00 A.M. Then another cluster of balloons burst and the apparatus descended at about 2,000 feet per minute, reaching the surface of the ground at 9:20. The signals were lost in the receiver at an altitude of only a few hundred feet, indicating a not distant horizon.

(b) Experience in Following the Flight with a Theodolite.

The flight was kept continually in view in a standard meteorological balloon-theodolite. Altitude and azimuth angle readings were taken every five minutes. The altitude of the balloons being known from the regularly transmitted pressures, the horizontal distance of the flight from the theodolite could be determined at any time. Knowledge of the distance and the azimuth angle permitted a plot of the balloons' position. The balloon-flight could be plainly seen when it was forty miles away and 40,000 feet up. On a good day it should be possible to follow such a flight for considerable distances, the chief hazard being the likelihood of losing the balloons in a cloud or in the sun or in smoke or haze on the horizon. Actually this flight was lost to sight in haze at about 10,000 feet on its descent.

(c) Techniques for Handling Many Balloons.

The problem of handling nearly seventy balloons and launching a flight with static forces of about 175 pounds presented an interesting problem. The balloons were inflated by three crews of three men each, the total operation requiring about 2½ hours. The balloons were of Neoprene and according to the manufacturer's instructions had to be warmed in hot water for five minutes before inflating. This was accomplished in a large kettle, heated by three gasoline blow-torches. After inflation the balloons were tied off and carried out onto the field from which the flight was to be launched. Each was covered by a cheesecloth cover* about 5 feet square, to the corners of which a bag containing lead shot was secured. Thus each balloon had its own anchor. The balloons were arranged at their proper place along the rigging which had previously been laid out on the ground. Each balloon was then tied to the rigging, but was still under its cheesecloth cover and anchored. Eleven clusters of six balloons each plus a single lead-

* This use of cheesecloth and individual anchors is part of a technique developed by the University of Chicago Cosmic-ray group.

balloon were used, making a total of 67 balloons. Fig. 6 shows the complete flight about to take off.

Above the third cluster from the bottom a Dowmetal ring four inches in diameter was inserted in the rigging. A line was passed through this, which permitted manoeuvring the flight when it was in the air just prior to release. At the launching signal, the line was released at one end and cleared through the ring. A second ring was

FIG. 6A. Launching operation. The balloons are attached to the rigging in clusters and the lead-balloon, in the distance, is about to be released. The instrument is behind the camera. (Chicago Daily News Photo.)

tied into the line just above the instrument, and a second mooring-line was passed through it. In addition, two short fixed lines permitted final adjustments after the other lines had cleared. Thus when the balloons were in the air, a total of six lines held the flight in place until the signal for release was given. This arrangement permitted all final checks, adjustments and tests to be made with the balloons in the air supporting the weight of the instrument. The instrument could be raised as much as ten feet above ground while the mooring ropes were

held. Also, the ring part way up the rigging avoided the necessity of any one group of the flight crew having to handle the entire static strain, which was thus divided among the several crews until the balloons

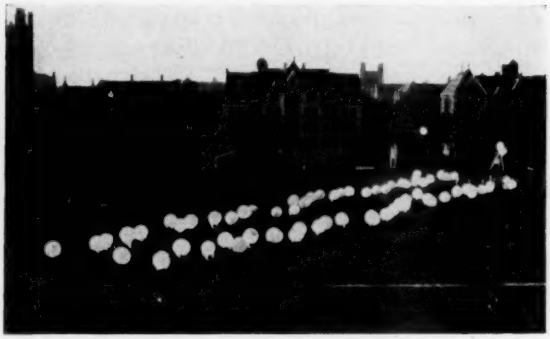

FIG. 6B. The balloons individually anchored about the rigging just prior to release. Lead balloon at left, instrument at distance at right.

FIG. 6C. The complete instrument, in its cellophane cover, receiving final checks.

lifted the instrument, after which only the free lift had to be checked by the crews.

(d) Recovery Operations.

The balloon theodolite provided information about the altitude and azimuth angle which, combined with the knowledge of the height from the transmitted pressure-data, enable the operator to plot the position

of the flight on a map at any desired time. It was found that if the location was plotted every ten minutes, adequate knowledge of the position of the flight could be obtained. In the original plan, an automobile was to have started after the flight had been in the air for half an hour or so and had established a definite direction in which it appeared that the flight would drift. In this case the flight went slowly

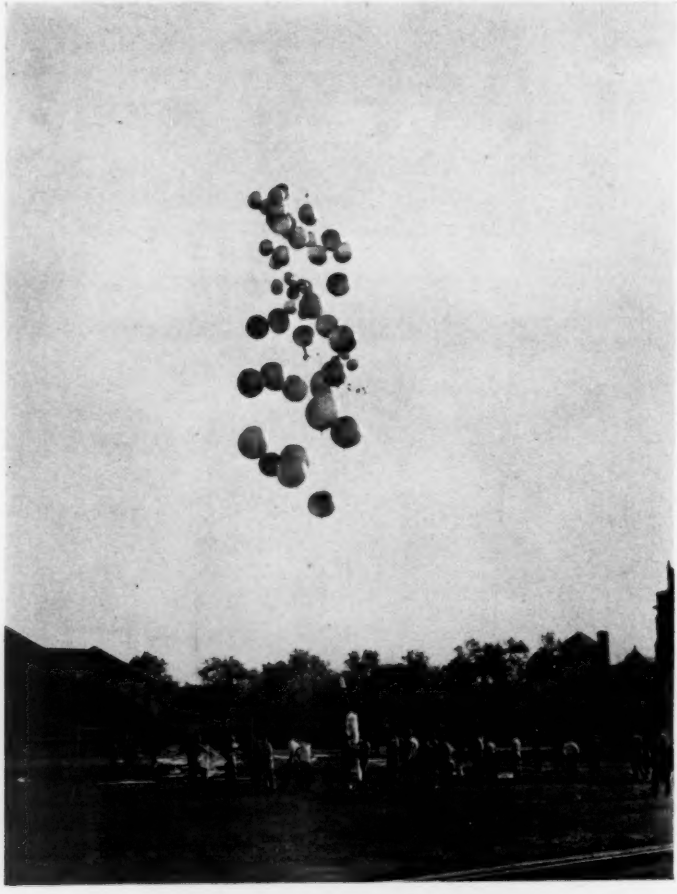

FIG. 6D. Launching the balloon flight. (Photo by R. E. Lapp.)

out over Lake Michigan, so this plan was not put into effect. It is believed, however, that such a plan is entirely practical, provided that the personnel in the automobile telephone the observing station every half-hour or so to ascertain the most recent movements of the flight. Since the average ground-speed of the flight is not very different from that of an automobile, it should be possible to have the automobile arrive at the landing-place within half an hour of the time the instru-

ment lands, provided the distances and velocities are not excessive and roads are reasonably good. If the flight should be lost in the balloon-theodolite, extrapolation using the last-observed distance and vector velocity is necessary. Since the rate-of-descent of such instruments has been found to be practically a constant, two points on the descent curve permit prediction of the time of landing. This has been tried on several flights and the times have been predicted within a few minutes of those observed. Further, on past flights, application of the horizon formula, taking the horizon altitude as that at which the signals suddenly fade out, has given surprisingly good results. It will be recalled that the

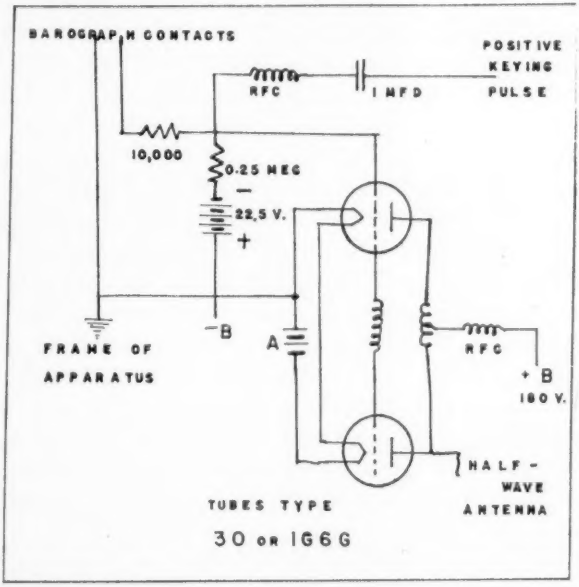

FIG. 7. Electronic keying. To eliminate keying relay, transmitting oscillator is held nonoscillating by negative bias, is caused to oscillate by positive keying-pulse. Radiobarograph contacts ground the grid, also permitting oscillation. Resistances in ohms, capacities in microfarads.

distance of the horizon, d, in miles is related to the height h in feet of the instrument through the equation

$$d = 1.25\sqrt{h}$$

where the constant 1.25 is an approximate figure dependent on the location of the receiving antenna and on the topography of the surrounding terrain. The exact value should be determined by test for each station.

(e) Alternative Radio Techniques.

Several alternative radio techniques have been used in recent flights and a review of the successful ones is perhaps worth while.

In order to eliminate the keying relay employed in previous flights to actuate the transmitter, a circuit for electronic keying of the oscillator was developed. This circuit is shown in Fig. 7. It will be noted that the oscillator is held in a "non-oscillating" condition by the negative grid bias, but that, upon application of a positive pulse to the grid through the condenser, the transmitter is allowed to oscillate. This oscillation and hence the signal length is determined by the RC time of the condenser and the grid bias resistor. A value of 0.25 second using a 1 mf. condenser and 0.25 megohm resistor was chosen for the Chicago flight to give a signal of sufficient length to record unambiguously yet short enough not to be confused with the barograph contact signals. The barograph merely connected the grid of the oscillator to its cathode, through a low resistance and a radio frequency choke which kept radio frequency voltages in the oscillating circuit. By other similar contacts of different time-constants, the same oscillator could also be caused to emit signals of any other desired length. Further, the barograph contacts worked in the grid circuit and therefore broke extremely small currents, a consideration of importance in securing uniform contact lengths and helping to avoid burning or arcing at the barograph contacts.

Receiving antennas have usually been the half-wave doublet type. However, a J-type antenna was also tried and found satisfactory. The question has also been discussed as to whether a directional receiving antenna could be used successfully, to supplement or to replace the balloon theodolite. In the event of a cloudy day or a distant flight, such an arrangement may prove successful, but as long as the instrument remains visible, the theodolite has so much better angular definition as to make certain its superiority over the other arrangement.

ACKNOWLEDGMENTS.

The authors wish especially to acknowledge the assistance received from Professor Marcel Schein, Messrs. Sumi, Ticho and Iona and their collaborators and assistants in the Chicago cosmic-ray group. Without their enthusiastic cooperation and active aid, which included the necessity of the entire balloon-crew arising several times at 3:00 A.M., the flight would not have been possible. The instrument was built by L. G. Collyer. He and S. Friedland accompanied the trip to Chicago and also assisted with other operations. Financial support was received from the Carnegie Institution of Washington.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

SUNSPOTS AND RADIO COMMUNICATION.

One of the largest sunspot groups ever seen crossed the solar disc between January 29 and February 11, 1946 and was accompanied by very pronounced radio and other terrestrial effects. This sunspot group partially returned, after one rotation of the sun, between February 27 and March 13. It was again associated with terrestrial effects, though much less severe. The maximum area of the group on first passage in February was greater than one hundred square degress of the sun's visible disc or about 100 times the area of the earth. According to the United States Naval Observatory the group was the largest on record since 1892; it was easily visible to the naked eye through smoked glass.

The region around the sunsport was observed to be very bright in the light of the hydrogen alpha line and several solar eruptions or flares were seen. Associated with these flares were sudden ionospheric disturbances manifested by radio fadeouts. These are caused by a sudden great increase in ultraviolet light which creates such high ionization in the D region of the ionosphere that high-frequency radio sky waves are absorbed. These sudden fadeouts usually last from a few minutes to several hours. They are most severe on the lower of the high frequencies above the broadcast band. Propagation paths nearer the subsolar point (noon, equatorial region) are disturbed the most. Since this type of disturbance is caused by a solar eruption, only a radio propagation path of which a part is in sunlight is affected. The Bureau's radio receiving station at Sterling, Va. recorded sudden ionosphere disturbances on January 29, 30, and 31, and February 1, 2, 3, 6, 7, 8, 9, and 11 (i.e., almost every day while the sunspot was on the solar disc). The most severe of these was on February 6, when almost all signals were blacked out for $3\frac{1}{2}$ hours. Five and a half hours passed before field intensities were fully recovered on some of the paths.

The leader spot began to pass the sun's central meridian on February 4, but the follower spot, which was the larger and more significant, did not pass the central meridian until the early hours of the Greenwich day of February 6. A little over 24 hours later, a period which agrees well with the theoretical time required for particles to travel from the sun to the earth, severe terrestrial disturbances were noted. Brilliant displays of aurora borealis were reported, with some auroral display actually visible at Washington on the nights of February 6 and 7. A great

* Communicated by the Director.

geomagnetic storm began suddenly at 1019 GCT on February 7, according to the Cheltenham, Md., magnetic observatory of the United States Coast and Geodetic Survey, and lasted until 2300 GCT on February 8. This very severe disturbance was followed by two moderate geomagnetic storms on February 9 and 10. Moderate storms had also been reported on February 3, 5, and 6. The level of horizontal magnetic intensity was abnormally low from February 7 through 9 and remained below normal until February 12.

Warnings of the radio transmission conditions expected because of this solar outbreak were issued by the Interservice Radio Propagation Laboratory at the Bureau. Daily warnings of disturbed radio conditions, primarily on transmission paths across the North Atlantic, were issued, February 7 to 11. In addition, the semiweekly forecasts issued February 1 and 5 predicted poor transmission for February 4 to 11. The daily warnings of expected disturbed conditions were broadcast from the Bureau's station WWV and by other means.

Reports subsequently received by the Bureau, on ionospheric and radio traffic conditions, indicated that radio communications were severely disturbed at all latitudes north of Washington, on February 7 and 8, and were moderately disturbed from then on through February 11. This type of radio disturbance is characterized by rapid or flutter fading, accompanied by very weak field intensities. The higher frequencies are usually blacked out because of abnormal depression of the critical frequencies of the F2 layer of the ionosphere, and direction-finder observations become unreliable. After the most severe part of this disturbance was over, the daytime hours were characterized by very high absorption, as indicated by very weak field intensities. This prolonged type of disturbance is most noticeable on the radio transmission paths crossing the auroral zone. For this reason the reception of all European stations in the United States was difficult or impossible during this ionosphere storm.

The leader of the sunspot group returned to the solar disc on February 27 and the follower on February 28. The group as a whole was somewhat less than half of its original size but was still in the class of large sunspots. The follower, the significant part of the group, crossed the sun's central meridian on March 6 and was last seen on March 13. The group was shrinking in size as it disappeared from view. While it is possible that the follower spot will return a second time about March 27, it will probably no longer be of the large sunspot class.

Sudden radio fadeouts were again associated with flares from the general region of the sunspot group. The Sterling, Va. station recorded sudden ionosphere disturbances on February 27 and 28 and March 1 and 8. The associated radio fadeouts lasted from $\frac{1}{2}$ to $1\frac{1}{2}$ hours. Thus, there were fewer disturbances of shorter duration with the return group than with the original group.

Geomagnetic storms were reported by the Cheltenham, Md., magnetic observatory on March 4 to 6, March 9, and March 10 to 11; the last was the most severe, but the disturbance was much less severe than the one that accompanied the original sunspot group.

Daily warnings of radio propagation disturbance were issued by the Bureau on March 5 and 6 and again on March 9, extending to March 12.

There was not an exact 27 day recurrence of the prolonged ionospheric disturbance of February 7 through 11, which was forecast as a possibility for March 6 through 9 in the semiweekly forecasts issued March 1 and 5. Rather, there was slight to moderate radio propagation disturbance indicated on March 5, with moderate disturbance beginning March 10 extending through March 11. Though the times of these disturbances did not show the expected relation with the central meridian passage of the sunspots, the region of the return sunspot group was the most likely source of disturbance visible on the sun.

Summarizing, severe radio and other terrestrial effects were very pronounced during the original passage of the sunspot group in February, and were less pronounced during its return in March.

SERVICEABILITY OF OPTICAL GLASS.

Several modifications of a powder-hygroscopicity method have been tried as a rapid means of determining the serviceability of optical glasses, that is, their ability to maintain a clear polished surface under normal conditions of service. The method has been applied by Donald Hubbard, of the Bureau's Glass Section, to a wide variety of glasses and, as reported in the *Journal of Research* for April (RP1706), it shows that the typical optical glasses in common use are much less hygroscopic than the average commercial sheet and container glasses. In fact, many of the optical glasses even compare favorably with the better chemical laboratory wares such as Pyrex, Tamworth, and Kimble N-51-a. This grouping of glasses of such dissimilar chemical durabilities serves well to emphasize that the capacity of a glass to maintain a clear surface upon exposure to the atmosphere, and its chemical durability as conveniently determined, are two inherently different properties. A comparison of the hygroscopicity values of the Corning 015 electrode glass with those of the optical and chemical ware glasses, the electrode capacity of which is very poor, suggests strongly that the pH response of a glass is primarily a function of its hygroscopicity. Tests made on a limited number of glasses of the binary series Na_2O-SiO_2, K_2O-SiO_2, Li_2O-SiO_2 and PbO-B_2O_3 appear to reflect some of the critical compositions of the respective phase equilibria diagrams.

SPECTROGRAPHIC DETERMINATION OF BORON IN STEEL.

The addition of a few thousandths of one per cent. of boron to certain steels results in an increase in the hardenability (depth of hardening).

This property suggested the possibility that boron could be substituted for considerably larger portions of strategic alloying elements in steel and, consequently, intensive studies of boron steels were made during the war period. In view of the low concentrations of boron required for optimum hardening (usually 0.001 to 0.003 per cent.), and the effect of variations in concentration on the properties of the steel, accurate and rapid methods were required for its determination. An investigation of the applicability of spectrographic methods to this problem was carried out by Charles H. Corliss and Bourdon F. Scribner at the Bureau under the sponsorship of the War Metallurgy Committee, and supported by funds allotted by the Office of Production Research and Development of the War Production Board. The report on this work will be published as RP1705 in the April *Journal of Research*.

The investigation showed that the sensitivity and accuracy of spectrographic methods for determining boron were affected considerably, under certain excitation conditions, by the size and shape of the steel electrode or by other variables that result in changes in its rate of cooling. These effects arise from a high volatility of boron (probably as oxide) which, in steel production, is manifested in losses from melts of steel. Advantage was taken of this volatility in the development of spectrographic methods for its determination.

Two spectrographic methods, suitable for high speed routine analysis, were developed. The first involves a.c. arc excitation with $\frac{7}{32}$-inch steel rods for determinations down to 0.0006 per cent. boron with an average deviation of $\pm$ 4 per cent. The second method applies to massive pieces of steel in any size or shape, using an over-damped condenser discharge providing sensitivity and accuracy equal to that of the first method. These methods are rapid and reliable, permitting routine determinations in the usual range of boron concentrations in less than 20 minutes per sample.

A third method, of highest sensitivity, was developed for determinations as low as 0.0001 per cent. boron, or 1 part in one million of the steel sample. This method utilizes a d.c. arc to which sodium is added to suppress an interfering spectral line of iron arising from energy changes in the ionized iron atom. In the course of the investigation, a series of 6 boron steels was issued as National Bureau of Standards Standard Samples for application of the spectrographic methods in industrial and military laboratories. The six standards are in two sizes, $\frac{7}{32}$-inch and $\frac{1}{2}$-inch rods, and cover the range of 0.0006 to 0.019 per cent. of boron.

CORROSION OF STAINLESS STEEL SHEET IN MARINE ATMOSPHERES.

Under the sponsorship of the National Advisory Committee for Aeronautics, the Army Air Forces, and the Bureau of Aeronautics of the

Navy Department, Willard Mutchler of the Bureau's Metallurgy Division has been studying the corrosion of thin stainless steel sheets for use in aircraft likely to be exposed to marine atmospheres or to be wetted frequently with sea water.

Information was obtained concerning the effect of certain factors upon corrosion. Those considered were: (1) the presence of small quantities of stabilizing elements in steels containing approximately 18 per cent. of chromium and 8 per cent. of nickel, (2) locality of exposure, (3) shot-welding, (4) surface finishes and treatments, and (5) contact with light metal alloys.

The 0.018 inch thick sheet samples were exposed to the weather, and intermittently or continuously in sea water, at Hampton Roads, Va., Kure Beach, N. C., and Chapman Field, Fla. Samples were removed after approximately 6, 12, 24, and 36 months of exposure. The damage from corrosion was usually evaluated by means of flexural fatigue tests and visual examinations.

The tests disclosed that the most rapid corrosion occurred during the first 6 months' exposure, and that thereafter the rate of attack was much slower. After 3 years of exposure at Hampton Roads, most of the alloys failed in fatigue tests at from 78 to 85 per cent. of their initial (uncorroded) endurance limits. The steels containing from 2.5 to 3.5 per cent. of molybdenum were much less susceptible to rusting or weathering than those containing titanium, columbium, or no stabilizing elements. None of the steels rusted appreciably when immersed in sea water. The loss in fatigue limit values, however, was approximately the same at the three locations in both weather and sea water, indicating that pits were present. Panels exposed to the weather at Kure Beach exhibited the greatest loss and the most rust. Shot-welds were slightly more susceptible to rusting than the rest of the sheet. The amount of rust decreased, other factors being constant, as the degree of surface polish improved. Pickling prior to passivation increased the resistance to corrosion. Aluminum and magnesium alloys, especially the latter, were rapidly corroded when exposed in contact with the stainless steels. Suitable paints at the faying surfaces were adequate in preventing corrosion on the light alloys for from 6 to 12 months of weather exposure at the marine localities.

SOLUBILITY OF CADMIUM SULFATE IN HEAVY WATER AND IN NORMAL WATER.

Determinations of the solubility of cadmium sulfate in heavy water and in normal water have been made by Langhorne H. Brickwedde as an extension of the study of the effect of heavy water on the electromotive force of the standard cells that serve as primary standards of electromotive force in this country and throughout the world.

As reported in the April *Journal of Research* (RP1707), cadmium

sulfate was found to be about eight per cent. less soluble in heavy water than in normal water. The transition temperature for the two hydrates $CdSO_4 \cdot 8/3\ H_2O$ and $CdSO_4 \cdot H_2O$ is 43.6° C., whereas for $CdSO_4 \cdot 8/3\ D_2O$ and $CdSO_4 \cdot D_2O$ it is 45.4° C.

CALORIMETER FOR MEASURING SPECIFIC HEATS OF GASES.

A flow calorimeter built for determining the specific heats of such gaseous hydrocarbons as butadiene, isobutene, styrene, and ethylbenzene used in the manufacture of synthetic rubber, was given a thorough test with pure (electrolytic) oxygen. The test with oxygen was intended to ascertain the accuracy of the apparatus by making a comparison between the specific heats observed with it and those calculated from spectroscopic data. Measurements were made at −30°, +40°, and +80° C.

The results exceeded expectations. Using the Berthelot equation of state to reduce the observed specific heats at the pressure of the gas in the calorimeter to values at zero pressure for comparison with the specific heats calculated from spectroscopic data, the differences between the calorimetric and spectroscopic specific heats were only a few parts in 10,000. When the Beattie-Bridgeman equation of state was used the agreement was not quite so good, especially at ±30° C. where the difference amounted to about 1 part in 1,000. It is planned to try an empirical equation of state developed by C. H. Meyers of the Bureau's Heat Division, which fits the observed p-v-t data for oxygen over a wide range of temperatures and pressures.

Small differences between the observed and calculated specific heats of oxygen could be accounted for by slight errors in the calibration of the thermocouple used to measure the temperature rise, so it is concluded that the fundamental design of the calorimeter is satisfactory. The principal criticism of the apparatus is that the measurements are time-consuming. Three operators are required and three or four days' work are necessary to obtain data at one temperature. Further improvements in the calorimeter should include automatic controls, to reduce the number of operators required, and a reduction of the heat capacity of the calorimeter so that measurements can be made more rapidly.

At present the apparatus is being used to measure the specific heat of isobutane, a petroleum hydrocarbon which enters into the manufacture of synthetic gasoline, and is the starting material for the manufacture of butyl rubber. The data obtained will be combined with measurements by others of the heat capacities of solid and liquid isobutane for calculating tables of its thermodynamic properties for use by chemical engineers.

THE FRANKLIN INSTITUTE

MEDAL DAY MEETING.

WEDNESDAY, APRIL 17, 1946.

The annual Medal Day exercises at The Franklin Institute began at 6:45 p.m. on the evening of Wednesday, April 17th. Members and friends of the Institute who were unable to attend the dinner were present for the presentation of awards which began at 9:00 p.m.

A Reception was given by the Hostess Committee to the Medalists and their friends preceding the dinner.

At 9:00 o'clock the program of the evening began, with Mr. Charles S. Redding, President of the Institute, presiding.

He called upon Captain Guy Marriner, member of the staff, recently released from the Army of the United States, to play the National Anthem.

Mr. Redding then announced that this was the monthly meeting of the Institute and stated that the minutes for the February meeting, published in the March JOURNAL, were presented for approval or correction. As no corrections were offered, the minutes were declared approved as printed.

The program and list of awards follow:

PROGRAM.

Reception to Medalists ..... THE HOSTESS COMMITTEE

Dinner ..... MEDALISTS, OFFICIALS AND GUESTS

NATIONAL ANTHEM ..... GUY MARRINER

Toast to Benjamin Franklin ..... RICHARD T. NALLE
Chairman, Board of Managers' Committee, National Franklin Committee

Greetings ..... CHARLES S. REDDING
President, The Franklin Institute

Introduction of Medalists of Other Years ..... THE PRESIDENT

"Reconversion" ..... HENRY BUTLER ALLEN
Secretary and Director, The Franklin Institute

Presentation of Awards ..... THE PRESIDENT

"Research for Better Nutrition" ..... HENRY CLAPP SHERMAN

"Teamwork in Research" ..... HENRY THOMAS TIZARD
(Paper read by W. Laurence LePage)

"America" ..... GUY MARRINER

MEDALISTS.

Presentation of Certificate of Merit

RONALD D. DODGE
Manager of the Development Engineering Department
Electric Writing Machine Division
International Business Machines Corporation
Poughkeepsie, New York

Presentation of Wetherill Medal

LEWIS A. RODERT
Principal Engineer
National Advisory Committee for Aeronautics
Ames Aeronautical Laboratory
Moffett Field, California

Presentation of Brown Medal

KARL TERZAGHI
Lecturer in Soil Mechanics
Graduate School of Engineering
Harvard University
Cambridge, Massachusetts

Presentation of Henderson Medal

TRACY VERO BUCKWALTER
Formerly Vice-President (now retired)
Timken Roller Bearing Company
Canton, Ohio

Presentation of Levy Medal

GEORGE CLARK SOUTHWORTH
Radio Research Engineer
Bell Telephone Laboratories, Incorporated
New York City, New York

Presentation of Potts Medals

IRA SPRAGUE BOWEN, Director
Mount Wilson Observatory
Pasadena, California

BENGT EDLÉN
Professor in Physics
University of Lund
Lund, Sweden

SANFORD A. MOSS
Consulting Engineer
General Electric Company
Lynn, Massachusetts

Presentation of Cresson Medal

GLADEON M. BARNES, Major General
Chief, Research and Development Service
Ordnance Department
United States Army
Washington, D. C.

Presentation of the Franklin Medal and Certificate of Honorary Membership

HENRY CLAPP SHERMAN
Mitchill Professor of Chemistry
Columbia University
New York City, New York

Presentation of the Franklin Medal and Certificate of Honorary Membership

HENRY THOMAS TIZARD, President
Magdalen College
Oxford University
Oxford, England

A detailed statement of these exercises will be printed in full in an early issue of the JOURNAL.

HENRY BUTLER ALLEN,
Secretary

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Wednesdays, and Fridays from nine o'clock A.M. until five o'clock P.M., Thursdays from two until ten o'clock P.M., Saturdays from nine o'clock A.M. until twelve noon as of June 1, 1946.

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ERRATUM

THE CHARGE EFFECT IN RELATION TO THE KINETICS OF PHOTOGRAPHIC DEVELOPMENT. II. T. H. JAMES.—*A correction.*

Communication No. 1032.

Equation (3) of this paper (*J. Franklin Inst.*, **240**, 86, 1945) is in error, and should read:

$$dD/dt = k' - \frac{D}{\delta}(d\delta/dt). \qquad (3)$$

In the derivation of the equation, the constant, C, of Equation (1) is neglected, since it is very small. No induction period is to be expected on the basis of the corrected equation. Although the precise variation of the quantity, $\frac{D}{\delta}(d\delta/dt)$, cannot be stated for the experiments in question, this quantity should increase or, in the extreme case, remain constant with increasing development in the early stages. Thus, dD/dt should *decrease* or remain constant.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Enzymes Hydrolyzing Ribo- and Desoxyribonucleic Acids.—CHARLES A. ZITTLE. Enzymes hydrolyzing ribonucleic acid and desoxyribonucleic acid are present in calf intestinal mucosa (1). For the present studies this material was partly purified (ME) by the procedure of Schmidt and Thannhauser (2) for alkaline phosphatase, without the aluminum hydroxide treatment. These preparations contained 12,500 units of alkaline phosphatase * per gram assayed by the method of Huggins and Talalay (3). The preparation of Schmidt and Thannhauser (2) (ribonucleinase was absent) hydrolyzed ribonucleic acid. ME hydrolyzed ribonucleic acid completely, measured by its solubility in uranium reagent (4), in which nucleic acid components larger than mononucleotides are insoluble, and by the appearance of inorganic phosphate. This hydrolysis took place with the liberation of acid, measured by the CO_2 liberated from a $NaHCO_3$ medium, pH 7.5. Mononucleotides are intermediates in the hydrolysis of desoxyribonucleic acid by intestinal mucosa enzyme (5) and presumably the same is true of the hydrolysis of ribonucleic acid and the secondary phosphoric acid groups are being measured. The striking difference (see Fig. 1) between ME and ribonucleinase, which also liberates acid under these conditions (6), should serve to distinguish these enzymes since only the former is active with low concentrations of ribonucleic acid.

The calf intestinal mucosa enzyme hydrolyzes desoxyribonucleic acid (1) only after the latter has been depolymerized by chemical or enzymatic means (7, 8). For the present studies desoxyribonucleic acid prepared by the method of Hammarsten (9) was depolymerized with an enzyme prepared from beef pancreas by the initial steps in McCarty's procedure (10), which apparently gives tetranucleotides (11). It was confirmed (10, 8) that the product was soluble in HCl; with uranium reagent (4) the amount of precipitate was the same before and after depolymerization. After ME had acted on the desoxyribonucleic acid-tetranucleotides a precipitate was no longer obtained with this reagent. With the desoxyribonucleic acid-tetranucleotides the liberation of acid by ME is about the same as with ribonucleic acid (Fig. 1) in respect to rate and influence of concentration of substrate.

In the fractionation of the calf intestinal mucosa performed so far phosphodiesterase activity (acid liberated from the nucleic acids) and the phosphomonoesterase activity (alkaline phosphatase) have run

* The phosphatase determinations were performed by Dr. Francis E. Reinhart in connection with another program.

parallel. Activity of the latter has been greater than the former but this is in line with the observations of Schmidt and Thannhauser (2) on diphenyl- and monophenylphosphates. These authors believed one enzyme hydrolyzed both esters. The present studies and those of others suggest that the enzyme hydrolyzing ribonucleic acid and desoxyribonucleic acid-tetranucleotides, and alkaline phosphatase of animal origin are identical (this enzyme is of broader specificity than ribonucleinase which hydrolyzes only about a third of ribonucleic acid to mononucleotides). The reported isolation of phosphomonoesterase

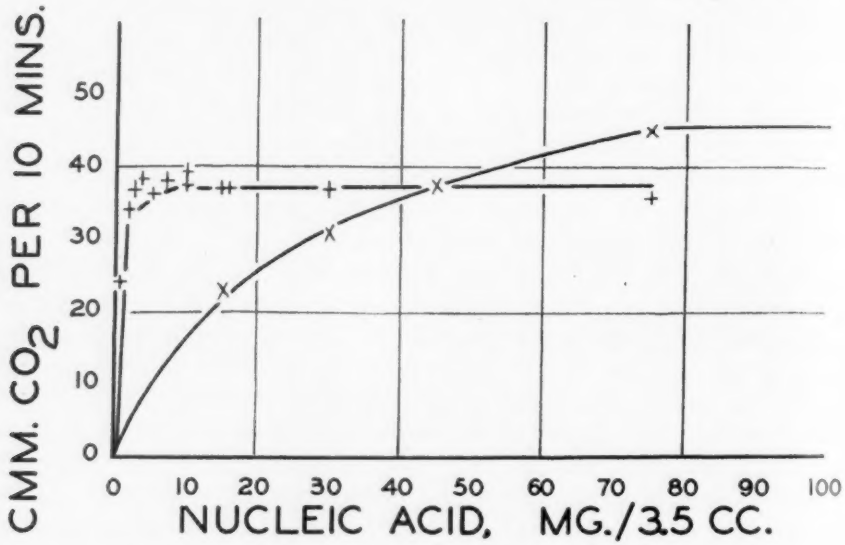

FIG. 1. Activity of ribonucleinase and intestinal mucosa enzyme with various concentrations of ribonucleic acid. Ribonucleinase (×): 10 γ of enzyme with 1.0 cc. of 0.1 M $NaHCO_3$, an atmosphere of 5 per cent CO_2 − 95 per cent N_2, pH 7.5, total volume 3.5 cc. Intestinal mucosa enzyme (+): same conditions with 0.4 cc. of a solution of ME (about 1 per cent. solid matter). The optimum activity of ME lies above pH 7.5.

free of phosphodiesterase (12) is at variance with this hypothesis but may have another explanation, for example, the activity of alkaline phosphatase with monoesters is over 100 times greater than with diesters (2). Only the isolation of the pure enzyme can definitely decide this question. It appears, however, that with only two enzymes (desoxyribonucleic acid-depolymerase and alkaline phosphatase) ribonucleic acid and desoxyribonucleic acid may be hydrolyzed to nucleotides and nucleosides.

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BOOK REVIEWS.

TABLES OF ASSOCIATED LEGENDRE FUNCTIONS. Prepared by the Mathematical Tables Project. 303 pages, 19 × 27 cms. New York, Columbia University Press, 1945. Price $5.00.

The use of mathematical tables is constantly expanding with the realization of their worth in applied mathematics in engineering as well as in scientific research. In recognition of this the National Bureau of Standards has sponsored a program in which major emphasis was placed on the computation of tables directly related to the war effort. The present table of associated Legendre functions was made to meet urgent needs for a table to about six significant figures at intervals of 0.1. At this interval in the argument, interpolation in these functions is not everywhere satisfactory. To render them reasonably interpolable over the entire range covered requires considerable further work which will appear in a supplementary volume.

The functions $P_n^m(X)$, $Q_n^m(X)$ and their first derivatives are tabulated in this volume for integral and half integral values of n, integral values of m, and real and imaginary values of x. The functions of $P_n^m(\cos\theta)$ and their first derivatives with respect to θ are also tabulated for integral values of n and m.

The work will take its place alongside other time saving mathematical tables. It is a valuable tool for those who need it.

R. H. OPPERMANN.

SCIENCE AND SCIENTISTS IN THE NETHERLANDS INDIES, edited by Pieter Honig and Frans Verdoorn. 491 pages, illustrations, 18 × 27 cms. New York, Board for the Netherlands Indies, Surinam and Curaçao, 1945. Price $4.00.

Some fifty-five papers and several shorter notes and reports have been gathered by the editors to offer a picture of the development and status of various branches of the natural sciences, pure and applied, in the Netherlands Indies. Many of the articles were especially prepared for this volume, some are reprints of papers originally published elsewhere, while a few are extracts from travel accounts left by distinguished visitors of the past.

The emphasis is on biological and agricultural pursuits, there being articles on agriculture, veterinary sciences, forestry, rubber, five chapters on cinchona, as well as articles on various research stations. Of more general interest would be the articles on climate, earthquakes and vulcanology, geology and mineral resources. Chemistry and astronomy in the Netherlands Indies are the subject of other chapters and engineering is represented by an account of hydrodynamic research.

The life and work of Rumphius, the blind seer of Amboina are made better known by a chapter devoted to this great hero of the East Indies. "The Puzzle of Pithecanthropus" represents an important summary of paleoanthropological discoveries in Java. A supplement contains a list of scientific institutions, societies and workers in the Netherlands Indies at the time of the Japanese invasion.

Although not a really complete history of science in the Netherlands Indies, due to the difficulty of wartime compilation, the editors have chosen their material well with the result that one obtains a stimulating view of scientific activity in this distant part of the world, until recently so little known to Americans.

GEORGE E. PETTENGILL.

THE MILKY WAY, by Bart J. Bok and Pricilla F. Bok. Second edition. 224 pages, illustrations, 15 × 22 cms. Philadelphia, The Blakiston Company, 1945 Price $2.50.

There are many questions about the milky way that are puzzling today although much more is known than in the past. This great band encircling the sky has fascinated men through

the ages and it has resulted in increasing study. During the past fifty years most Milky Way research has been done with the aid of photographic telescopes. While the evidence thus presented is basic, it is quite incomplete in spots.

The book is in its second edition after a lapse of four years. Additions and changes have been made so that the information is up-to-date. Written in a popular vein it explains what is known of this large flat stellar aggregation in which the stars move in intricate, though basically simple paths. At the outset the problem of variation of star brightness is attacked, and the methods and techniques used by astronomers described. Then examination is made of the sun's nearest neighbors—a sample of our galactic system taken within two or three hundred light years of our sun. Armed with this, the work sets out to analyze the observations on stellar distribution for more remote parts of our milky way. This leads to the questions of what are the general outlines of the system, and where is the sun located with respect to the galactic center, consideration of which involved data on star motion and velocities. The subject of bright and dark nebulae, interstellar gas, and the general haze are discussed and limitations in present knowledge are pointed out, and the path of modern milky way research described. The final chapters of the book deal with speculations based on present knowledge as to the age formation of the milky way, and the progress and direction of recently revealed facts.

The work is interesting and provides a greater appreciation for the serious minded reader.

R. H. OPPERMANN.

WAVEFORM ANALYSIS, A Guide to the Interpretation of Periodic Waves, Including Vibration Records, by R. G. Manley. 275 pages, tables and illustrations, 14 × 22 cms New York; John Wiley & Sons, Inc., London: Chapman & Hall, Ltd., 1945. Price $4.00.

The study of periodic variations is one in which workers in different fields make use of identical or similar mathematical processes although the physical significance of the variations may differ widely. Some of the most important are mechanical vibrations, alternating current electricity, acoustics, and tidal motions. This text has been prepared with the needs of scientists and engineers in mind to offer a guide in interpretation as the title suggests and to present a less cumbersome method than the Fourier analysis, known as the envelope method. This method is competant to handle most varieties of wave forms containing two or three principal components.

After a brief introduction the work opens with general properties of sine waves and with the wave forms that can be produced by adding two different sine waves together. The properties of symmetry, skew-symmetry and alternance are treated and an account is given of the manner in which these properties indicate harmonic contents of a wave form. This lays the groundwork for the process of analysis. The approach then is through consideration of those waves of which the main characteristics can be observed directly in the waveform, and the manner in which desirable determinations are made. This leads to the envelope method of analysis evolved by vibration engineers. First the analysis with only two components is described. Various types of three component wave forms is next discussed, the technique being a logical development of that used for two component waves. A systematic scheme of analysis based on these various types of wave is given in the form of two tables the application of which is illustrated by means of actual recorded examples. The last example is of a wave form with four predominant components, and shows the limit of application of the method.

The determination of the components of the many complex waves which do not fall into the category susceptible of the above treatment are described in the succeeding part of the book. This section starts with the method of superposition, a method of dividing the cycle into a number of sub-cycles and determining the variation which is the average of the variations in the different sub-cycles. Then there is the well known Fourier Series, methods of numerical analysis utilizing a number of ordinates evenly spaced and a description of the Harvey machine type of mechanical analyzer. The latter part of the book is devoted to practical requirements for wave forms and Lissajou figures which are figures produced by the motion of a point whose plane Cartesian co-ordinates both vary sinusoidally. There are a number of helpful appendixes, a glossary, bibliography, and index.

The book is a good practical guide and text for giving appreciation of the properties of complex waves.

R. H. OPPERMANN.

ELECTRON OPTICS AND THE ELECTRON MICROSCOPE, by V. K. Zworykin, G. A. Morton, E. G. Ramberg, J. Hillier and A. W. Vance. 766 pages, drawings and illustrations, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1945. Price $10.00.

Within the very few years that the electron microscope has been available for research it has left its imprint on most branches of experimental science. This process may be expected to proceed at an accelerated pace. To an ever greater extent this research is becoming quantitative, rather than purely qualitative. It is important, therefore, that present and prospective microscopists have a thorough understanding of the instrument. This book, written by men intimately associated with the development of the electron microscope, is intended to fill this need.

The first part of the book opens with a qualitative introduction to the principles of electron optics and a survey of its applications. These sections are succeeded by a description of the different types of electron microscopes, stressing instruments other than the magnetic electron microscope. Next the design principles of the several components of the magnetic electron microscope are outlined, the most successful instruments are described in detail, and the operation tolerances of the magnetic electron microscope are given. A chapter is devoted to the construction of suitable electric power supplies for the microscope. The first part closes with a chapter on the techniques of electron microscopy and a general survey of the research accomplishments of the new instrument.

The second part of the book begins with a discussion of the theoretical basis of electron optics. Chapters dealing with the measurement and calculation of electrostatic fields, the tracing of electron rays through such fields, and the properties of various types of electrostatic lenses (and mirrors) follow in sequence. They are succeeded by analogous treatments of magnetic fields and magnetic lenses. The aberrations of electron lenses are derived in systematic fashion and discussed quantitatively, possible ways of correcting them being pointed out. The modifications introduced by the variation of the electron mass with its velocity at high accelerating potentials, as well as those due to the greater mass of ions in ion optics, are treated in a later chapter. The final chapter summarizes our present knowledge of the process of image formation in the electron microscope. A brief discussion of noise problems arising in connection with electron multipliers and with the scanning microscope, as well as a few useful tables, form an appendix to the book.

The method of presentation is simple and direct. The book furnishes an aid to the wide circle of those interested in applied optics.

R. H. OPPERMANN.

ATOMIC ENERGY IN WAR AND PEACE, by Gessner G. Hawley and Sigmund W. Leifson. 211 pages, illustrations, 13 × 20 cms. New York, Reinhold Publishing Corporation, 1945. Price $2.50.

Only a small part of the general public is able to digest the details of the atomic bomb project put forth in the report prepared for the War Department by Professor H. D. Smyth of Princeton. The available literature of a briefer extent is in many stages of technical language, so that it is somewhat discouraging to those who wish to acquire some knowledge of the work. To provide a ready means of becoming acquainted with the achievement of the atomic bomb and its portent for peace, this book has been written.

Much effort has been expended in preparing the reader for the discussion of the release of atomic energy. In this the atomic theory is discussed in the layman's language including the elements and the periodic system. Molecular structure is then touched upon referring briefly to chemical compounds, but more specifically to the reactions releasing energy in molecules. The technical extent of this is up to simple chemical formulas which are used as illustration.

Several substances are discussed with relation to latent energy and this leads to a discussion of explosive compounds and the nature of gases. Potential energy and kinetic energy are defined.

All of the above is given as basic for the presentation on the atomic structure. A good, interesting, and informing coverage is given on this, encompasing an idea as to the sizes of the particles composing an atom and then distances apart, neutrons, photons, protons, electrons, etc. The descriptive matter on energy is very cleverly made, clear but yet flexible. From here the work leads to isotopes, radioactivity, gamma rays and finally nuclear disintegration. The work which was done on uranium, the products of plutonium and neptunium, the apparatus used, and the almost unsurmountable difficulties are pictured in an impressive style. These details of the atomic bomb project follow closely the report of Professor Smyth. For reasons of security, of course, certain information is withheld.

The latter part of the book is devoted to the military future of atomic energy, then the peacetime future. There is a subject index in the back.

The story reads easily, in fact the knowledge and events are so well portrayed that the reader must marvel at the wonderful achievements so well unfolded before his eyes. The book is one for the layman having only a smattering of scientific background. It provides sufficient information to carry on a light intelligent conversation.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Colloid Chemistry, edited by Jerome Alexander. Volume VI. 1215 pages, drawings and illustrations, 15 × 23 cms. New York, Reinhold Publishing Corporation, 1946. Price $20.00.

Elements of Ammunition, by Major Theodore C. Ohart. 412 pages, illustrations, 15 × 23 cms. New York: John Wiley & Sons; London: Chapman & Hall, Limited, 1946. Price $6.00.

Our Oil Resources, edited by Leonard M. Fanning. 331 pages, tables and illustrations, 14 × 21 cms. New York and London: McGraw-Hill Book Co., Inc., 1945. Price $4.00.

The Cavendish Laboratory, by Alexander Wood. 58 pages, illustrations, 10 × 17 cms. New York, The Macmillan Company, 1946. Price $1.00.

Semi-Micro Quantitative Organic Analysis, by R. Belcher and A. L. Godbert. 168 pages, drawings, 14 × 22 cms. New York, Longmans, Green and Co., 1945. Price $3.00.

CURRENT TOPICS.

ARMY AND NAVY NOTES.

Floating Power Plant Supplies Antwerp With Emergency Power.—A queer looking, propulsionless barge, incapable of motion and seemingly relegated to home front duty during the war, not only crossed the Atlantic and entered combat but supplied the city of Antwerp, Belgium, with emergency electric power for several months, it was disclosed recently.

Named the "Resistance," the craft was a huge American floating power plant with no "git up and git" of it own but with a General Electric turbine generator set capable of generating enough electric power to supply a city of 100,000. Looking more at home on the Mississippi than on oceanic waterways, the "Resistance" was one of many such floating power plants built to meet temporary power shortages expected in the United States in the early stages of the war.

Nevertheless, when it became necessary to "draft" the propulsionless craft for combat action, Uncle Sam found a way. Under vigilant eyes of a Naval convoy, the "Resistance" was towed by the Army Transportation Corps the entire distance across the Atlantic. Averaging a speed of three knots per hour, the craft took 51 days to make the crossing.

The voyage was logged as comparatively quiet until the convoy reached the Scheldt estuary at which point German U-boats, moving in for a kill, struck a running fight with the "Resistance's" escorting craft. The attackers were destroyed after a full night's engagement.

Arriving off Antwerp, the huge floating power plant was connected directly to lines of the Belgian power system, and for several months thereafter Antwerp received its electric power from the "Resistance." During the period, the Germans poured in 2,600 V-bombs in an attempt to destroy the port, but the power barge remained unscathed of any serious damage.

Housed in a steel hull half the length of a city block, the power plant was able to generate a maximum of 30,000 kilowatts of steam turbine power with its General Electric turbine generator set. Steam was supplied to the turbine by two oil fired boilers that consumed a half million gallons of fuel oil in about seven days.

A 20 foot transmission tower built on the deck provided the means of hooking up the plant to Belgian power lines.

R. H. O.

Electro-Acoustic Laboratory.—The Electro-Acoustic Laboratory, the first laboratory at Harvard to engage in National Defense Research, has just closed its doors after five years of highly secretive and significant war work for the Army, Navy and Marine Corps.

Under the directorship of Dr. Leo L. Beranek, the Laboratory, conceived in November 1940, received its first commission from the Army Air Forces. It was assigned to investigate means for quieting the noises inside long-range

bombing planes so that the personnel could do their job with less fatigue. A few months after that, it received its second and most important assignment, which was to make communication possible between the crews of aircraft flying at altitudes above 20,000 feet.

For the first project, the laboratory set to work to find a material or materials which would alleviate the excess sound in the airplane cabins. They tested many substances and finally hit on the fundamental idea that the important thing about an acoustical material for use in aircraft is that the area of the fibers which are in it should be large compared with their weight. Out of this discovery grew a new material sold under the trade name of Fiberglas AA. This material is made from thousands of glass fibers which are only a micron in diameter, that is, 1/100 of the diameter of a human hair! These glass fibers are coated with a plastic binder which holds them together in the form of a bronze colored blanket that is ½ inch in thickness and weighs 1/20 pound per square foot.

In sound treating an airplane an optimum method of installing the material was developed. This installation consisted of two ½ inch blankets of the Fiberglas sewed on opposite sides of a sheet of asbestos paper, and the combination was mounted inside the plane about 3 inches away from the "fuselage skin" or walls. The assembly was covered with a decorative cloth trim. This method of reducing noise was highly successful and most long range military planes manufactured after 1941 were treated in this manner. The Boeing Super-Fortress, one of the quietest military planes flying, was the laboratory's most outstanding example of successful quieting.

In the fall of 1941, the Electro-Acoustic Laboratory was asked by the Navy Bureau of Aeronautics if they could improve materially the operation of communications systems in aircraft. "Two aspects were involved," said Dr. Beranek. "First was the determination of the way in which the human voice and the equipment varied as the atmospheric pressure was reduced to the very low values existing above 20,000 feet; and secondly was the recommending of new equipment designs to be adopted and manufactured for use at high altitudes." During this program, the laboratory worked closely with the Psycho-Acoustic Laboratory at Harvard under the direction of Dr. S. S. Stevens. That laboratory tested the communication equipment, using a procedure called "articulation testing." Articulation testing is conducted in the following manner: A person reads selected words over a communication system while it is operating under flight conditions and a group of listeners write down those words they understand. The percentage of words correctly recorded is called the articulation score. New devices for improving communication systems were built at the Electro-Acoustic Laboratory and sent over to the Psycho-Acoustic Laboratory for articulation tests.

"One of the fundamental things which we felt we needed to know was how the human voice varied as a function of altitude," Dr. Beranek related. "A year of hard work under the supervision of Mr. H. W. Rudmose, Associate Director of the Laboratory, resulted in the development of a complex machine called an 'audio spectrometer' which split up the sounds of speech into thirteen different bands—one band covering the very low tones, another band covering slightly higher tones, etc., until all the tones produced by the voice were included. This machine was moved over to the Harvard Public School of

Health where a large altitude tank is located. Because no young men the age of average fliers could be obtained to do the talking, volunteers from Conscientious Objectors' Camps on the East Coast were solicited and eight men volunteered to take part in these hazardous tests. These men, wearing suitable oxygen masks and equipped with microphones and earphones, were taken up to an altitude equivalent to 40,000 feet for two-hour stretches, where they read sentences, words and vowel sounds over the microphones. The audio spectrometer measured how loud they were talking in each of the different tonal bands. Every week they were given complete physical examinations, including electro-cardiograms and X-rays of the lungs."

Several very interesting things were learned. First, the human voice decreases in intensity at 35,000 feet to a value of about 1/10 of its strength on the ground. No change in hearing was found. As a result of these discoveries, special amplifiers were built whose amplification automatically increased as they were carried to higher and higher altitudes. It was also found that the tonal quality of the voice changed with altitude. At 35,000 feet the consonants seemed unusually distinct, and there was a booming of the voice in the lower register. A lack of quality was added by the nasal passages. The talker experienced some difficulty—his nose felt stuffy and his throat cottony. There was an inability to speak more than two or three words without taking a breath. Also, the presence of the oxygen mask changed the tonal quality of the voice—amplifying the low notes. The microphones and the amplifier had to be built so that they amplified the higher notes more than the lower ones, thus removing the booming sound.

One portion of the laboratory's work demanded the construction of a special room called an "Anechoic Chamber" (meaning "without echo"). This remarkable room was built to simulate the atmospheric conditions existing at one to three thousand feet above the earth. The walls are almost perfectly absorbing, that is, less than 1/1000 of the sound which strikes a wall is reflected. This same situation exists above the earth where there are no buildings, walls or ground to reflect sound.

This chamber is completely windowless and is housed in a concrete building whose internal dimensions are 38 × 50 × 38 feet and whose side walls are one foot in thickness. There are no pillars or beams inside the room. The walls are lined with 20,000 wedge-shaped structures made from eight carloads of Fiberglas PF Insulating Board having a density of 2.5 pounds per square foot.

R. H. O.

Powerful New Gunnery System for Final Blow Against Japs.—Details of the revolutionary gunnery system that enabled the Army Air Force's spectacular attack bomber, the A-26 Invader, to play a vital role in bringing the Nazis to their knees and which has been introduced in the Pacific to help hasten the destruction of the Jap war machine were disclosed by General Electric, designer and builder of this deadly equipment.

Containing the first two-ended periscope gun sight ever used on combat aircraft, the A-26's deadly fire system gives a gunner "double vision" by permitting him to scan the skies in almost any direction for an enemy and to bring tremendous firepower to bear against him accurately and almost instantaneously. In the last stages of the German campaign the Army recently

credited the invader with playing a major role in destroying or damaging nearly 2,000 enemy vehicles fleeing from the Allied forces.

Major part of the A-26 gunnery system is the periscope gun sight, which passes completely through the fuselage of the plane, with sight heads emerging from both the top and the bottom. Remote control links the novel sight with two two-gunned turrets, so that each time the gunner moves his sight to follow an attacking plane the gun turrets move similarly, as if the two were one piece of equipment.

Both the upper and lower A-26 turrets and the periscope sight are controlled by a single gunner. He is located in comparative safety in a remote sighting station, where he is freed from distracting noise and shock and can hold his guns on the target without jarring or shaking, thus reducing bullet dispersion and permitting more accurate marksmanship.

The two-headed arrangement of the periscope sight allows a gunner to scan the skies for an enemy in the area above his own plane, to either side of it or beneath it. When an attacker climbs or dives from one hemisphere to another, a flip-over mirror within the instrument transfers the gunner's line of sight from one end of the periscope to the other and does so with such rapidity he never loses track of the target.

Gun turrets follow movements of the periscope sight so rapidly that the two move almost simultaneously. This precision of motion between the sight and the guns is made possible by ingenious electrical devices, called selsyns, which transmit an electrical message to other selsyns in the turret about which way the guns must move. After being amplified this electrical message is converted into power that runs motors and directs the turrets, bringing the guns quickly into alignment with the sight.

When an A-26 engages in death-in-the-sky combat with a Jap, only those guns on the turret covering the area in which the Nip is flying can be fired. But, as in switching the sighting from one end of the periscope to the other, a slight overlap in area makes certain no direction is left even momentarily uncovered. Turreted guns can be fired any place in a 360-degree horizontal circle and, in little more than one second, the upper turret can be raised from a level position to where it's shooting straight overhead, while, in the same time, the lower turret can be pointed straight down.

In battle action the A-26 gunner is seated so that he can revolve around the periscope tube, his eye to the sighting eyepiece, and follow the maneuvers of an attacking ship in any quarter of the sky. A series of concentric circles in the field of his instrument gives him the proper range in respect to his target, and, when an enemy is properly lined up in the sight, he presses triggers on his sight handle to fire the guns located many feet away.

Protection is afforded the gunner by a shield of armor plate which, as the gunner moves around the periscope tube to keep his sight trained on a rapidly maneuvering enemy, moves accordingly and covers him from enemy fire. Gun turrets of the A-26, because they house the .50-caliber machine guns but not the gunner, can be made small and streamlined and are placed so their firepower is concentrated most effectively.

Since the gun turrets are located several feet away from the gunner who aims and fires them, many times not being visible to him, special apparatus prevents them from being fired when aimed in a direction that might endanger

any part of the A-26 or its crew. Fire interrupters automatically keep the guns from being fired when aimed in such directions, while, at the same time, another device, called the contour follower, redirects the guns slightly, causing them to clear the A-26 fuselage.

G-E's remotely controlled gunnery system, developed in collaboration with Wright Field Armament Laboratory, equips the A-26, ordinarily a medium-altitude bomber, with the sting of a fighter. The fast, light plane itself, built by Douglas, can carry as heavy a load of bombs as any other plane its size, and, using several stationary guns and a cannon located in its easily modified, "all-purpose" nose, is expected to take a regular place alongside other mighty American planes.

The optical system for G-E's periscope sight, similar to optical systems used in submarine periscopes, was originally designed by Bausch and Lomb and was later modified by the Eastman Kodak Corporation. Both of these organizations, together with Farrand Optical Company, are building periscopes for the system.

Top speed of the A-26, which is powered by two Pratt and Whitney 2000-horsepower engines, is in excess of 350 miles per hour and cruising speed is 300 miles per hour. Besides the single gunner the combat crew includes the pilot and, when desired, an auxiliary crewman.

R. H. O.